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THE UNITED STATES
STRATEGIC BOMBING SURVEY

EFFECTS OF INCENDIARY BOMB ATTACKS ON JAPAN

A REPORT ON EIGHT CITIES

Physical Damage Division
April 1947

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Dates of Survey:

3 October 1945 — 1 December 1945

Date of Publication:

April 1947

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This report was written primarily for the use of the United States Strategic Bombing Survey in the preparation of further reports of a more comprehensive nature. Any conclusions or opinions expressed in this report must be considered as limited to the specific material covered and as subject to further interpretation in the light of further studies conducted by the Survey.

FOREWORD

The United States Strategic Bombing Survey was established by the Secretary of War on 3 November 1944, pursuant to a directive from the late President Roosevelt. Its mission was to conduct an impartial and expert study of the effects of our aerial attack on Germany, to be used in connection with air attacks on Japan and to establish a basis for evaluating the importance and potentialities of air power as an instrument of military strategy for planning the future development of the United States armed forces and for determining future economic policies with respect to the national defense. A summary report and some 200 supporting reports containing the findings of the Survey in Germany have been published.

On 15 August 1945, President Truman requested that the Survey conduct a similar study of the effects of all types of air attack in the war against Japan, submitting reports in duplicate to the Secretary of War and to the Secretary of the Navy. The officers of the Survey during its Japanese phase were:

Franklin D'Olier, *Chairman.*
Paul H. Nitze, Henry C. Alexander, *Vice Chairmen.*
Harry L. Bowman,
J. Kenneth Galbraith,
Rensis Likert,
Frank A. McNamee, Jr.,
Fred Searls, Jr.,
Monroe E. Spaght,
Dr. Lewis R. Thompson,
Theodore P. Wright, *Directors.*
Walter Wilds, *Secretary.*

The Survey's complement provided for 300 civilians, 350 officers, and 500 enlisted men. The military segment of the organization was drawn from the Army to the extent of 60 percent, and from the Navy to the extent of 40 percent. Both the Army and the Navy gave the Survey all possible assistance in furnishing men, supplies, transport, and information. The Survey operated from headquarters established in Tokyo early in September 1945, with headquarters in Nagoya, Osaka, Hiroshima, and Nagasaki, and with mobile teams operating in other parts of Japan, the islands of the Pacific, and the Asiatic mainland.

It was possible to reconstruct much of wartime Japanese military planning and execution, engagement by engagement, and campaign by campaign, and to secure reasonably accurate statistics on Japan's economy and war production, plant by plant, and industry by industry. In addition, studies were conducted on Japan's over-all strategic plans and the background of her entry into the war, the internal discussions and negotiations leading to her acceptance of unconditional surrender, the course of health and morale among the civilian population, the effectiveness of the Japanese civilian defense organization, and the effects of the atomic bombs. Separate reports will be issued covering each phase of the study.

The Survey interrogated more than 700 Japanese military, government, and industrial officials. It also recovered and translated many documents which not only have been useful to the Survey, but also will furnish data valuable for other studies. Arrangements have been made to turn over the Survey's files to the Central Intelligence Group, through which they will be available for further examination and distribution.

TABLE OF CONTENTS

Page

SECTION I. INTRODUCTION 1

II. REFERENCE TABLES 5

III. INDIVIDUAL REPORTS 7

Part 1. Effects of Incendiary Bomb Attack on Imabari, Japan 7

Part 2. Effects of Incendiary Bomb Attack on Oita, Japan 24

Part 3. Effects of Incendiary Bomb Attacks on Tokyo, Japan 65

Part 4. Effects of Incendiary Bomb Attack on Aomori, Japan 119

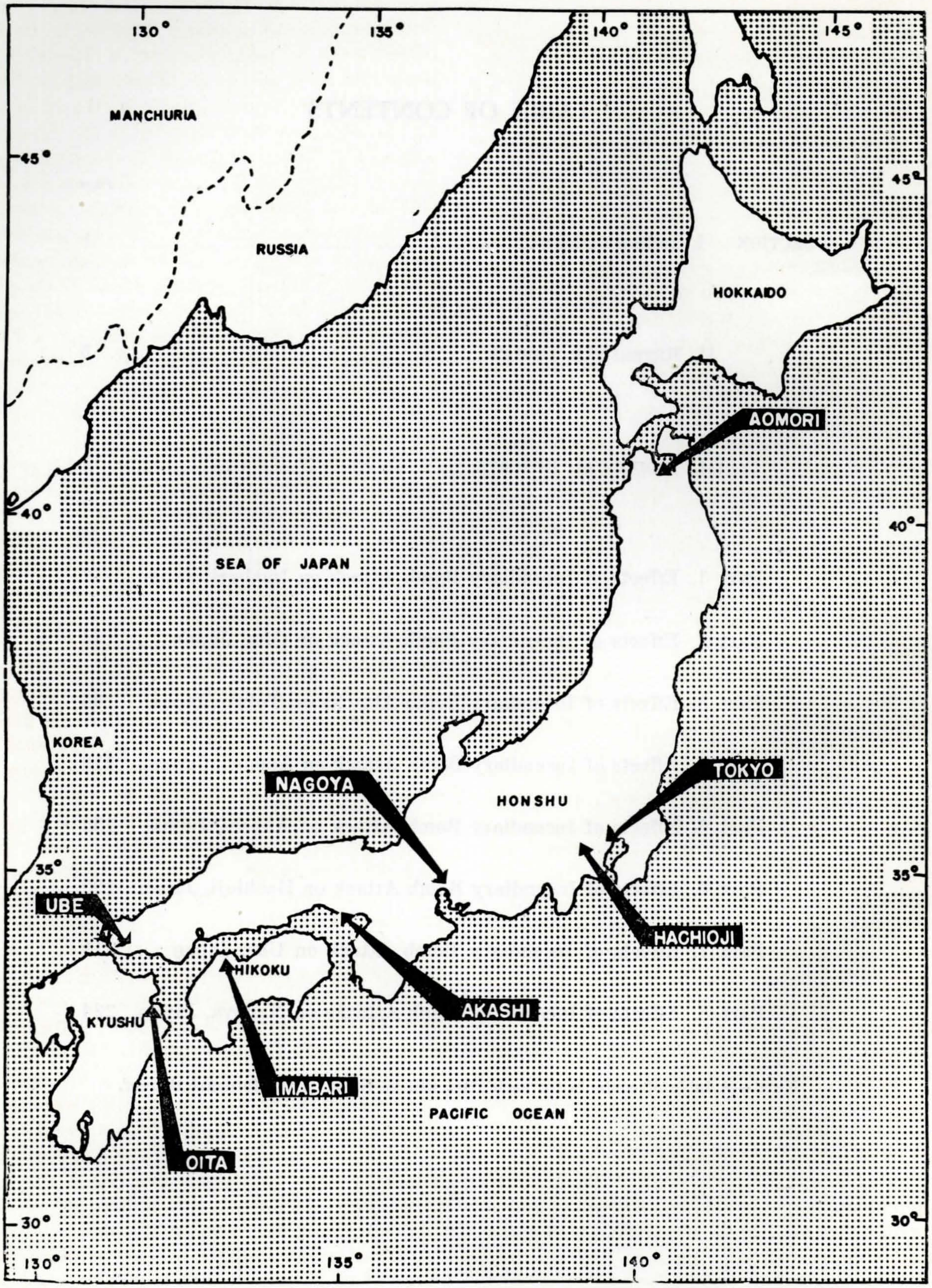
Part 5. Effects of Incendiary Bomb Attack on Akashi, Japan 159

Part 6. Effects of Incendiary Bomb Attack on Hachioji, Japan 190

Part 7. Effects of Incendiary Bomb Attack on Ube, Japan 211

Part 8. Effects of Incendiary Bomb Attacks on Nagoya, Japan 224

NOTE.—A table of contents for each Part will be found in the forepart thereof.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SEA OF JAPAN
KOREA
NAGOYA
HONSHU
TOKYO
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35°
UBE
HACHIOJI
HIKOKU
AKASHI
KYUSHU
IMABARI
PACIFIC OCEAN
OITA
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I. Introduction

1. The fire studies of eight Japanese cities contained in this report were made to determine the extent of fire damage and the effectiveness of bombs. Some consideration has also been given to the effectiveness of precautionary measures.

2. Of the eight cities, the two largest were selected because they were subjected to multiple attacks, and represented the most and least successful extremes; four were chosen because only one type of weapon in each case was used in attacks; one was significant because it was attacked by one type of incendiary bomb plus high explosives; and one small city was included because the attack on it was believed to have been highly ineffective.

3. It might have been desirable to make comparable studies on at least two cities, but difficulties arose from the fact that several different types of bombs were usually employed on the same target. Furthermore, it soon became apparent that ground features of the target and AAF tactics and accuracy had more influence on the extent of damage than did the type of bomb.

4. Considerable time has been devoted to fire defense, including the preparation of firebreaks, insofar as it affected the extent of damage. Civilian-defense matters are likewise touched upon in order to acquaint the reader with the facilities available for the protection of the civil population. Any conclusions derived therefrom are on the basis of the few cities studied and not on the comprehensive studies of the Civilian-Defense Division.

5. The teams making the studies were composed of men representing a wide range of experience, selected either because of previous studies in Europe or their peacetime occupations. In every case, at least one trained fire engineer, who had the responsibility of directing activities and preparing the report, was on the team. Weapons' specialists investigated the flight, penetration, ignition, and malfunction characteristics of the bombs. Structural engineers and architects studied the damage done to structures by fire, and the fire engineer investigated the degree of exposure fires, fire sprad, and fire-fighting forces.

6. The conclusions reached in any one report may be contrary to those in another report within the same volume. This is to be expected since no team made more than two reports and each was done independently. Such results as were found suitable for analysis and comparison have been reported in the Fire Section of the Physical Damage Division's over-all report. There, all the factors involved are considered and appraised; for example, a spreading conflagration occurred in Tokyo, but not in Nagoya; a fire storm was created in Hachioji but not in Imabari; firebreaks in Tokyo were not as effective as those in Nagoya. The reasons for such peculiarities of behavior are not contained in this report, but are in the over-all report cited above.

7. It was the original intent to make fairly detailed appraisals of the effectiveness of the bombs in each of the cities studied (the M69 in Imabari; M47 in Oita; M47 and M69 in Tokyo; M74 in Aomori; M69 in Akashi; M50 in Hachioji; M47 and M69 in Ube; and mixed incendiaries in Nagoya), but on arriving at the targets it was found that the areas were so completely devastated (the bomb cases had been removed and no records made of the bomb count, density, or malfunction) that the emphasis was shifted to establish the reasons for the damage or for the failure of the fire to progress. This procedure developed the fact that the time, rate of bomb delivery, density, built-upness, location of concrete and noncombustible buildings, and meteorological conditions played important parts in the extent of damage. The Japanese opinions as to how the attacks could have been made more successful are also given for what they are worth.

8. Studies of certain technical or little-used fire-fighting equipment were omitted from this report. Items such as the automatic sprinkler were not used widely enough in the Japanese cities surveyed to warrant their inclusion in the report. Others, such as safes and vaults, were not studied as personnel of the teams was not sufficiently specialized. Not much is made of the damage to fire-resistive buildings because not many were involved. Fire walls and fire doors were similarly omitted because of the lack of an adequate number of cases.

9. One of the subjects treated briefly is the effect of fire on the population. This subject

is important to everyone, for it is recorded that fire killed more persons than any other cause or weapon. The number of civilian deaths in Japan greatly *exceeded* the number of strictly military deaths inflicted on the Japanese in combat by the armed forces of the United States. This statement is pregnant with significance, for if there still be a doubt that the emphasis in warfare has shifted from military forces to the civilian populations, then this fact should dissipate all uncertainty.

a. The results of the air attacks were erratic. The number of persons killed in one attack on Tokyo (9-10 March 1945) was equal to the number killed in all other major attacks on Japanese cities. In this particular case, it is probable that more persons were killed in one 6-hour period by the least expenditure of bombs than in any other recorded attack of any kind. Only at Dresden, Germany, was the number of dead greater, and that was so because of the population's having been swollen by the influx of refugees and the prolonged attack having covered a large area. Hamburg, Germany, sustained the next greatest number of casualties: 41,800 known dead, and an estimated 37,500 seriously injured. Some 280,000 persons were made homeless in an area of 4.5 square miles of total damage and 12 square miles of heavy damage for an expenditure of 2,360 tons of bombs. By comparison, during the 10 March 1945 attack on Tokyo, 83,793 persons lost their lives, 41,000 were injured, and 1,000,000 were made homeless in 15.8 square miles of totally damaged area for an expenditure of 1,667 tons of bombs.

10. The high vulnerability of Japanese cities to fire made them ideal targets for incendiary attack; typical buildings of inflammable light-frame construction, density of urban areas with their narrow, congested streets and the widespread accumulation of combustible materials in and around both residential and commercial structure combined to create a constant invitation to disaster by fire.

11. The Japanese had given some thought to the protection of their cities and had taken certain precautions against the time when they would be subjected to aerial bombardment and incendiary attack, but their preparations, based upon assurances of the military that they would never be attacked in force, were woefully inadequate even when they had emerged from the planning stage which was often not the case.

12. Several results of the lack of thorough preparation were apparent. The people had been lulled into a feeling of false security and thus had no realization of the need for urgency or of the necessity of preparing elaborate passive defense; modern fire-fighting equipment was lacking and such as existed was generally of poor quality; there was no modern, efficient training program for either the paid firemen or the civilian-defense organizations; the lack of facilities to utilize the usually adequate water supply was especially striking; and procrastination in providing safe shelters for the populace and essential equipment proved disastrous when the crisis came. Also, firebreaks and fire lanes failed to fulfill their primary purpose, that of stopping the spread of fire, when incendiaries were dropped on both sides of lanes.

13. In the majority of cities the fire departments were far too small to provide more than moderate protection and that only in the event of routine fires within a comparatively small area. They were totally incapable of extinguishing and, in many cases, of even controlling to any degree whatsoever, the holocausts that swept through their cities following mass incendiary attacks. After it became obvious that combating the main fires was futile, their efforts for the most part were confined to the perimeter in an attempt to protect the more important buildings from exposure fires and to extinguish or control incipient fires ignited in isolated areas. Mutual aid from outlying districts was of little, if any, assistance. Many of the pieces of apparatus that did come in to help had run so low on their meager fuel supply that they were unable to operate or had to be abandoned to the flames; others arrived too late to be of use. In extenuation, however, it may be said that the conflagration conditions resulting from incendiary attacks would have rendered ineffective even the most modern fire department.

14. The water supply was generally considered adequate for ordinary fire-fighting purposes. The unusually heavy demands made on the systems under actual attack conditions,

however, together with the loss of pressure resulting from broken mains and melted pipes, quickly exhausted normal supplies and weakened the resistance of the fire-fighting elements. Where there was an unlimited water supply, complete utilization was not made of it, or, as was often the case, lack of suitable pumping equipment precluded its use. In one case studied where a sufficient water supply would have been available, the entire system was dependent on electric power. A bomb strike on the power plant early in the attack crippled the pumping equipment and left the city with only static water supplies for fire-fighting purposes.

15. The firebreak program, which was late in starting, was never completed to the degree planned. In the larger cities, buildings were demolished to create fire lanes 80 to 300 feet wide through congested areas, and wooden structures were removed from areas adjacent to some of the more important buildings to reduce fire hazard. Few such precautions, however, were taken in the smaller cities. In general, the man-made firebreaks had almost no effect on stopping the spread of fire since incendiary bomb loads were dropped over wide areas and ignited numerous fires on both sides of the lanes. In a few instances where bombs dropped on only one side of the firebreak, or the firebreak was located on the periphery of the conflagration area, the fire spread stopped at the break. These breaks or lanes did, however, serve as avenues of escape for persons who might otherwise have been trapped in burning areas, and occasionally these open spaces permitted access of fire apparatus to burning areas for limited operations, such as fighting isolated fires. In several cities fortunate enough to have large natural firebreaks (rivers, canals, parks and railroad yards) some degree of success in controlling fires was achieved by permitting them to burn in the direction of the breaks and concentrating fire-fighting efforts along the perimeter on the opposite side.

16. Air-raid shelters were insufficient in number and the majority was hopelessly inadequate for protection, being little more than shallow trenches with earth coverings supported by wood frames. Some of the better-constructed tunnel-type shelters, located outside congested city areas or in parks, offered from fair to excellent protection against high-explosive bombs, but within areas affected by large fires practically all types of shelters failed to serve their purpose, as occupants died from suffocation or the effects of intense heat even when not exposed to fire itself.

17. The weapons used in the incendiary attacks described in this report were the M47, 100-pound, oil-gel bomb; the M69, 6-pound, gelled-gasoline bomb; the M47, 10-pound, magnesium-gasoline and white phosphorus bomb; and the M50, 4-pound magnesium bomb. These bombs were especially effective in the densely built-up areas of cities where the flimsy construction and abundance of combustible material facilitated the spread and merging of numerous fires into huge conflagrations of terrifying and destructive magnitude. Virtually all combustible structures in the fire areas were consumed. Buildings of noncombustible construction suffered damage in direct ratio to the combustibility of their contents. Many fire-resistive buildings were gutted or were damaged to varying degrees by exposure fires. In several instances important factory installations and government buildings were saved from total damage at the expense of less vital buildings by the concentration of fire-fighting equipment and personnel.

18. The incendiary bombs were generally effective against industrial plants having thin roofs and moderately combustible contents. They did not perforate heavy reinforced-concrete roofs. The M50 incendiary had too much penetration for the average light-frame construction typical of Japanese dwellings; its high penetration, however, achieved unusual, if unexpected, success by breaking buried water mains in unpaved streets, thereby reducing the supply of water available for fire fighting.

19. The incendiary attacks on Japanese cities were highly effective in causing widespread damage. In several instances, it was considered that the bomb load was excessive for the target area, and that a smaller bomb load would have achieved the same proportion of damage. Variable factors, however, such as weather conditions, active opposition, and the obscuring of target by smoke, enter into this matter. It was likewise found at some of the targets that

the density within the bomb-fall area was not uniform; many bombs fell into areas already ignited or into sparsely built-up districts; and, on one target at least, it was considered that greater damage would have been caused had the fall of the bomb load been compressed into a shorter period of time. The effectiveness of the incendiary weapons lay to a large extent in the larger number dropped and the wide area covered, which nullified the protection of firebreaks and created an insuperable task for fire-fighting and civilian-defense organizations.

20. It was found that when subsequent incendiary attacks were made on the two largest cities the resulting damage by fire was generally lower in proportion to the tonnage of bombs dropped or, conversely, a greater bomb load was required to cause an equal amount of damage. This fact was accounted for by a part of the bomb load's falling on burned-out areas or those partly burned; by the probability that there was a lower concentration of combustible material to facilitate rapid fire spread; and by the fact that many of the larger burned areas served as firebreaks. It is believed that a series of attacks on a given target becomes more effective if the attacks are closely spaced within a period of not more than several days, which prevents repair of protective facilities and recuperation of defense agencies.

21. Production in cities hit by large-scale incendiary attacks was drastically reduced. This effect was brought about, first, because many plants were heavily or totally damaged by fires, either as a result of direct bomb strikes or by fire spread. Second, normal plant operations were curtailed by (1) plant employees being rendered homeless by fires; (2) damage to facilities supplying the plants, such as water, electricity, gas and transportation; (3) damage to the plants' own facilities; (4) loss of innumerable home workshops which supplied parts to the plants; (5) loss of raw materials; (6) damage to finished parts and (7) deaths and injuries among employees. In many cases, the production loss was greater than the percentage of damage sustained by a plant would seem to warrant.

22. This report covers damage by fire in the following target cities: Imabari, Oita, Tokyo, Aomori, Akashi, Hachioji, Ube and Nagoya. The fire stories on Hiroshima and Nagasaki will be found in Physical Damage Division Reports 69 and 70, respectively.

REFERENCE TABLES

TYPES OF DAMAGE

Damage to Buildings, Industrial and Domestic

a. Structural: Damage to principle load-carrying members (trusses, beams, columns, load-bearing walls, floor slabs in multi-story buildings) requiring replacement or external support during repairs. Light members such as purlins and rafters are not included.

b. Superficial: Damage to purlins and other light members; stripping of roofing and non-load-bearing exterior walls. Damage to glass and interior partitions not included.

Damage to Machinery, Utilities and Equipment

a. Total: Not worth repair.

b. Heavy: Requiring repair beyond capacity of normal maintenance staff; usually returned to manufacurer.

c. Slight: Requiring repair within capacity of normal maintenance staff.

Damage to Contents Other than Machinery and Equipment

a. Total: Not usable.

b. Other: Usable if reprocessed or repaired.

BUILDING TYPES OR CLASSIFICATIONS

(Tables A and B from Joint Target Group)

TABLE A

Group		Type symbol	Description
A. Single-story, no traveling cranes, spans generally less than 75 feet, heights at eaves generally less than 25 feet, area of 10,000 square feet or more.	1. With saw-tooth roofs	A1.1	All buildings of this group with saw-tooth roofs other than those included in Types A1.2, A1.3, and A1.4.
		A1.2	Frame and roof slab of monolithic reinforced concrete.
		A1.3	Exposed top chords of trusses.
		A1.4	Stressed-skin type of reinforced concrete (e.g. Zeiss Dywidag).
	2. Without saw-tooth roofs	A2.1	Simple beam and column.
		A2.2	Arches and rigid frames.
		A2.3	Truss construction.
		A2.4	Frame and roof slab of monolithic reinforced concrete.
		A2.5	Stressed-skin type including concrete shell.
B. Single-story with traveling cranes; any length of span; area of 10,000 square feet or more.	1. Buildings housing heavy cranes	B1	Buildings containing runways for heavy cranes (capacity 25 tons or more); height at eaves generally more than 30 feet.
	2. Buildings housing light cranes	B2	All buildings in this group other than those in B1.
C. Single-story; no traveling crane runways; spans greater than 75 feet; height at eaves generally greater than 25 feet; area of 10,000 square feet or more.	1. Main frame members in two directions	C1.1	Roof trusses supported along one side of building by long span trusses and along other side by columns. Permits large door along one side and at ends.
		C1.2	Continuous trusses in one or two directions; long span in one direction, supported by columns or exterior walls and by internal columns.
		C1.3	Exposed chord saw-tooth roof buildings; exexposed chord trusses supporting major size trusses at 90°. One or both truss systems may be of long span.
		C1.4	Diamond mesh arch.
	2. Main frame members in one direction only	C2.1	Long-span arches, individually supported along sides of building. May be arranged in multiple spans joined along side.
		C2.2	Long-span, triangular or bowstring trusses, individually supported by columns at sides of building. May be arranged in multiple spans joined along side, using common columns. Roof pitch exceeds 2 in 10.
		C2.3	Long-span trusses, top cord of pitch 2 in 10 or less, including exposed cord saw-tooth roofs, individually supported by columns along sides of building. May be arranged in multiple spans using common columns or may be continuous over internal columns.
	3. Shell-type construction	C3	Stressed-skin including concrete shell construction.
D. All single-story buildings of less than 10,000 square feet plan area.		D	This type covers all single-story industrial buildings, regardless of type of construction if under 10,000 square feet in plan area.

TABLE A (Continued)

Group		Type symbol	Description
E. Multi-story frame buildings.		E1	Earthquake-resistant; extremely heavy steel or reinforced-concrete, multi-story construction, designed to resist heavy lateral loads.
		E2	Structures in this group other than those in E1.
F. Multi-story, wall-bearing buildings. (May have internal columns.)		F1	Earthquake-resistant, wall-bearing construction. (Walls of brick, reinforced concrete, or very massive masonry.)
		F2	Structures in this group other than those in F1.
S. Special Structures		S	Coke ovens, test cells, fuel storage, boilers in power plants, etc.

TABLE B

HE VULNERABILITY CLASSES

HE vulnerability class	Substructural groups (Symbols refer to Table A)
V1	E1.
V2	B1, B2.
V3	E2, F1.
V3A	F2.
V4	A1.1, A1.2, A1.3, A2.1, A2.2, A2.3, A2.4, D.
V4A	C1.2, C1.3, C1.4, C2.3.
V5	A1.4, A2.5
	C1.1.
	C2.1, C2.2.
	C3.

FIRE CLASSIFICATION—BUILDING AND CONTENTS

C—*Combustible.*—Buildings whose roofs and/or walls are constructed of combustible material. The floors (except the ground floor) are required to be of similar construction. Wood-frame buildings with noncombustible sheeting on roof and/or walls are also included in "combustible" class.

N—*Noncombustible.*—Buildings which have no significant amount of combustible material in the structure, but whose structure is susceptible to damage by fire in the contents. An example of this type is a building with exposed steel members which may be warped irreparably by the heat of a fire. Roofs of this type are: Corrugated asbestos, corrugated iron, pre-cast or pour-in-place cement or gypsum on exposed steel, and reinforced concrete 2½ inches thick or less.

R—*Fire-resistive.*—Buildings which have no significant amount of combustible material in the structure and which will withstand all but the most intense fire without structural damage. Roofs and floors (other than ground) should be of concrete more than 2½ inches thick, and the steel frame should be protected and not subject to ordinary fire damage.

C & N, N & R or C & R used where above types are combined in a single fire division.

SECTION III

Part 1

EFFECTS OF INCENDIARY BOMB ATTACK ON IMABARI, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 9

II. SUMMARY 9

III. GENERAL INFORMATION 9

IV. THE TARGET 10

V. THE ATTACKS 11

VI. FIRE ATTACK DATA 12

VII. ANALYSIS OF DAMAGE 13

VIII. RECOMMENDATIONS AND CONCLUSIONS 14

Photos 1–15, inclusive

Figure 1

Table 1

I. Object of Study

This study was made to determine the effect of a highly concentrated incendiary-bomb attack on a small Japanese city with a large concentration of industrial operations.

II. Summary

1. Imabari, the second largest textile producer in Japan, occupied a 0.97-square-mile area along the straits on the northwestern tip of Shikoku Island. Approximately 0.6 square mile of the city was residential area. Police estimated the population at 60,000 persons just before the attack under study. Residences in this city were typical Japanese light, wood-frame, tile-roofed structures. The industrial area, which included textile dyeing, ship building and light bulb manufacturing plants, was located along the northern edge of the city. Three of the large plants had been converted in whole or in part to the manufacture of machine gun bullets, ailerons and small aircraft parts. Of the industrial buildings, the majority was of concrete with corrugated, asbestos-cement roofs on wood or unprotected steel trusses (Photos 15 and 9). Because of the absence of either artificial or natural firebreaks in the city, and because of the high combustibility of most of the buildings, the conflagration hazard was high. At the time of the attack, there was no motor-driven fire equipment in the city. The 300 volunteer firemen were trained in bucket brigade tactics. Industrial plants had fairly well trained fire-fighting personnel, but no equipment. The water supply was good.

2. American intelligence reported four attacks on Imabari. Two of these were reported to have been against an airfield and an aircraft engine plant, respectively. The Japanese denied that such facilities existed in Imabari and they had no record of such attacks. The Japanese reported an attack by Navy Grumman planes in addition to two AAF attacks. The attack under study was made at 0005 hours, 6 August 1945, and complete data are listed in Table 1. The principal weapon used was the M69 incendiary bomb, but fragmentation and general-purpose (GP) bombs were employed for antipersonnel effects.

3. Little effort was made either by the fire department or by individuals to fight the fire. There was no equipment other than hand type and the number of fires was so great that all measures were ineffective. Police reported that the fire had completely burned out in 5 hours, most of the dwellings being consumed by fire in about 2-hours time. Neither fire walls nor firebreaks would have been of value since, according to information obtained from interviews, bombs fell over the major portion of the city. The total built-up area covered 0.97 square mile, of which 0.69 square mile or 71 percent was destroyed. It is estimated that 85 percent of all dwellings was burned. There were several small, unburned areas located principally on the fringe of the city and along the waterfront. Damage to industrial plants was extensive, 27 of the 40 known plants being burned. Several large plants at the edge of the city which were hit by only a few bombs had minor fires which were extinguished by the employees.

III. General Information

1. The investigating team as a subdivision of Tokyo Area Team 6, and consisted of the following personnel:

Maj. G. P. Guill	Team chief.
Maj. R. L. Hughes	Structural engineer.
Maj. T. F. Gallagher	Ordnance.
Maj. J. E. Hatcher	Chemical engineer.
Maj. H. V. Keepers	Fire damage analyst.
Maj. E. F. Buckholdt	Ordnance.
Capt. W. G. Wells	Architect.
Capt. J. H. Leary	Chemical engineer.
1st Lt. T. K. Cribb	Ordnance.
1st Lt. J. S. Raines	Fire damage analyst.
2nd Lt. G. F. Poehler	Structural engineer.
2nd Lt. M. Yokoyama	Interpreter.
S/Sgt. R. H. Johnson	Draftsman.
PhoM 2/c J. D. Devore	Photographer.
T/4 M. Shimomura	Interpreter.
T/5 G. Tychsen	Interpreter.
Cpl. A. L. Epler	Draftsman.
Cpl. H. L. Born	Draftsman.
Pfc. N. J. Deluisi	Clerk, typist.

2. The investigation was begun 11 November 1945 and completed 15 November 1945. Weather was cool and clear.

3. Information contained herein was obtained from the following sources, all of which

are believed to be reliable: Yoshio Okai, chief of police; Yoshio Nakajima, deputy chief of police; Kanichi Yamada, interpreter and chief clerk for the police department; managers of several industrial plants, residents, and a Spanish missionary who was in Imabari at the time of the attack. Insofar as possible, all statements made by the Japanese were verified by observation, by study of documents, or by checking the substance of the statements through questioning several persons. All principal industrial plants were visited to ascertain the actual damage.

IV. The Target

1. Imabari, located on the northwestern tip of Shikoku Island, was the second largest cotton textile center in Japan. It occupied 0.97 square mile (0.6 square mile being residential) along the straits, the majority of the built-up area being contained within the boundaries of the Sosho River on the south, the railroad on the west and an irrigation canal on the north (Figure 1 and Photo 1). That portion along the Sosho River and the canal was given in part to rice paddies with a scattering of dwellings and isolated industrial plants. Several small canals ran through the city from west to east, and there was a large moated shrine near the center of the city. On the east was a small harbor with a prominent breakwater. The city was built on level ground, flanked by a low range of mountains to the west and south. The principal industrial area was along the northern edge of the city, but there was one large mill at the extreme south along the Sosho River. With the exception of a moderate-sized cotton mill adjacent to the moated shrine and a quartermaster depot located on reclaimed land along the water front, all plants were between the main highway and the railroad on the west. Population figures listed below were taken from the census and from Imabari police estimates:

1940 (census)	55,557
1945 (prior to attack)	60,000
1945 (during survey)	30,000

Members of the Team believe the last figure to be high, because a large percentage of the dwellings had been destroyed. It is probable that many persons who were in the city during the day actually lived in neighboring villages. Pre-attack population density in the central portion of the city was about 75,000 per square mile.

2. Residences in Imabari were of typical Japanese construction. The majority were one story, wood frame, with 1/2-inch-thick wood floors, covered with straw mats. The roofs were tile, set in mud, on wood sheathing and rafters. The walls were thin clapboard over mud and plaster on bamboo laths. The ceilings were 1/4- to 1/2-inch, unprotected wood. There was usually a small loft or attic for storage. The average framing used was 4 inch by 4 inch for the studs, with intermediate members 2 inch by 4 inch (Photo 2). These framing members were joined by mortise-and-tenon joints with very few nails or other metal used in the construction. In the downtown section, the buildings were largely two-story with a small shop occupying the ground floor and living quarters on the second floor. Most of the blocks were heavily built up except those on the outskirts, and they were separated by narrow alleys 12 to 18 feet wide. It was estimated that the built-upness of the city averaged almost 30 percent. The buildings were constructed in continuous block fronts between the narrow streets, and there were no fire walls.

3. The principal industrial operations were textiles (carding, spinning, and weaving), dyeing, shipbuilding, machine shops, and electric light bulb manufacturing. There were 26 cotton mills, employing a total of 4,000 persons, producing uniform cloth, canvas, and similar material for the Army and Navy. Three of the large plants had been converted in whole or in part to the manufacture of ailerons, 13-millimeter machine-gun bullets, and small aircraft parts. The machine shops were engaged in the manufacure of valves and other small parts for submarines and naval ships. Home industry was not highly developed in Imabari because of the highly specialized machinery required for most of the industries. Some machining of small parts was done in the homes, but on a much smaller scale than was usually found in Japanese cities. The industrial buildings were generally constructed with one-story, brick or concrete walls, and corrugated, asbestos-cement-covered roofs, supported on wood or unprotected, steel roof trusses of a saw-tooth

design (Photos 15 and 9). Floors were of wood or concrete. It was the general practice to surround the plants with a 10-foot brick or pre-cast concrete fence which separated the plant from near-by dwellings.

4. The conflagration hazard in the built-up area was severe. Block after block was subject to destruction because of the high builtupness (about 30 percent), because of the solid block fronts and inflammable construction, and because of the complete absence of either man-made or natural firebreaks. One main street through the center of the city, under favorable conditions, might have acted as a barrier, but since bombs straddled the street (determined through interview and finding of empty bomb casings) its existence did not prevent the spread of fire. The other streets in the city were actually narrow alleyways, 12 to 18 feet in width.

5. Fire department personnel consisted of four or five professional firemen and about 300 volunteers. The professionals included the fire chief and his assistants who trained and directed the volunteers in the rudiments of fire fighting, particularly in the action to be taken in case of air attack. This training included methods of escape from burning areas, aircraft identification, first aid, household fire fighting and use of the limited equipment available. The individual householder was given some training in the extinguishing of incendiary bombs and spot fires, and this training was intensified after the great fire attacks on Tokyo and other major cities. The industrial plants had individual fire brigades, but their equipment was limited to such items as stirrup pumps, buckets, sand boxes, and first-aid appliances. It was apparent from discussion with plant managers that special emphasis was placed on fire fighting, particularly in plants with a large amount of combustible construction.

6. Treated water for fire and domestic purposes was supplied from an irrigation canal through a 14-inch line to a 475,000-gallon, elevated reservoir, 148 feet above the city. This provided a static water pressure of 64 pounds per square inch. Supply to the city was through a single 18-inch line with a by-passed regulator valve. The distribution system consisted of 3-inch to 10-inch metal pipes. The fire hydrants were one-way, flush type except for seven which were a standard one-way type. There were two centrifugal pumps of unknown size, driven by 55-horsepower, electric motors. It was estimated that each of these pumps would deliver about 750 gallons per minute. A 75-horsepower Diesel engine was provided for emergency in case of failure of electric power. At the time of the attack, the elevated reservoir was practically full, and the pumps operated throughout the period. The water supply system was small, judged by United States standards, but was not unusual for a Japanese city. It was considered by the Japanese to be adequate to cope with normal fires.

7. The Imabari warning system consisted of a single siren located at the moated shrine near the center of the city. It was used for both fire and air-raid warnings. The few public shelters, shallow excavations in the sidewalk with about a foot of earth over wood covers, offered little protection from bombs and were often rendered unusable because of water seepage. Some of the industrial plants had fairly well constructed, earth-covered shelters along the perimeter of the plant grounds.

V. The Attacks

1. American intelligence indicates an attack by the Twentieth AF on 7 May 1945, in which 36 1,000-pound bombs and 56 2,000-pound bombs were dropped by 11 B-29 airplanes. The urban area was the target. No further American intelligence on this attack is available. Japanese officials estimate that eight B-29s made this attack. Observation of strikes and discussions with police indicated that instantaneous fuzes were used with the smaller bombs and variable long-delay fuzes (maximum 126 hours) with the 2,000-pound bombs. The Japanese made no attempt to remove the delayed action bombs, but evacuated the area and allowed the bombs to explode. The bomb track indicated that the direction of the attack was from SSW. No evaluation of the damage caused by this attack could be made, since the target was burned later. Japanese police state that in this attack the only motor-driven fire truck in the city was damaged beyond repair,

and this was verified by inspection of the vehicle.

2. Two additional attacks by the Twentieth AF are listed by the Machine Record Unit's consolidated record of air attacks in the Pacific Theater. The first of these, 25 April 1945, was directed against the Imabari airfield and was executed by 15 aircraft, carrying 66 tons of high-explosive bombs. The target of the second attack, 15 May 1945, was an aircraft engine factory, and the attack was carried out by one airplane, carrying three tons of high-explosive bombs. Japanese officials denied, however, that such installations existed in Imabari and stated that they had no record of either attack.

3. Japanese police reported a heavy strafing attack by a large number of Grumman carrier-based planes on 18 March 1945. A 2,000-ton transport was sunk and a 1,000-ton cargo ship burned.

4. The major attack (subject of this report) was made by the 58th Bombardment Wing of the Twentieth AF at 0005 hours, 6 August 1945 (Table 1) when 64 aircraft dropped 490 tons of M69 incendiaries. Weather prior to the attack, which lasted 42 minutes, was clear and warm with no wind. During the attack the weather remained clear but became overcast toward the finish. Immediately following the attack, a light rain began to fall and a light wind blew in from the sea. Psychological-warfare, tactical-warning pamphlets (T–3) were dropped sometime late in the day of 5 August, but this was done either a few hours prior to the attack or immediately preceding it and the effect was negligible.

VI. Fire Attack Data

1. *General.* The fire burned 0.69 square mile (71 percent) of the built-up area (Air Force damage assessment shows 0.73 square mile—76 percent). Eighty-five percent of the 0.6-square-mile residential area was destroyed, and 27 of the 40 industries in Imabari were damaged to such an extent that production ceased. A small area northwest of the moated shrine, a narrow strip along the water front in the northern portion of the city, and several blocks adjacent to the boat basin escaped damage. Only a small amount of the residential area west of the railroad was burned.

2. *Description of fire.* It is the opinion of the members of the team, based on observation of the burned area and discussions with police officers, plant owners, and residents, that there was very litte spread of fire from exposure. The large number of identified bombs found in the Kurashiki Cotton Mills area indicate a rather heavy concentration of incendiary bombs north and west of the built-up area of the city. The concentration in the city itself was heavy enough that the areas hit became saturated with fire in a very short time. Areas in which no bombs fell, or where only a few fell, remained intact, even though buildings within 50 feet or less were consumer (Photos 1, 4 and 5). Eye witnesses, principally police officials, stated that within an hour after the first bombs fell the entire area became involved.

Table 1.—Recorded Attack Data

Mission number	Date of attack	Type of target	Aircraft			Type of bombing	Altitude	Cloud cover	Bomb load					
			Type	Number air-borne	Number bombing				Type	Fuzing	Dispatched		released	
											Number	Tons	Number	Tons
?	7 May 1945	Urban	B-29	?	11	?	?	?	1000 G.P.	Variable max. delay 126 hours.	?	?	36	18
									2000 G.P.				56	56
58th Wing 20th A.F. No. 316	5-6 Aug. 1945	Urban	B-29	66	64	13 visual, 48 radar, 3 ?	12,200 to 12,800	0/10 to 5/10	500 M69 I.B.	Open at 5000 feet.	?	?	1960	490
									500 T4E4 frag. cluster.	Open at 3000 feet below aircraft.	?	?	48	12
									500 M60 G.P.	VT nose non-delay tail.	?	?	32	8

That the flimsy construction caused the buildings to burn readily and with great intensity for a short time was indicated by the increase in wind velocity from zero to 30 miles per hour. Melted glass and warped and twisted steel gave evidence of a quick, hot fire. Police reported that, except for isolated spots, the entire area was consumed in five hours and most of the residential buildings were completely burned in a much shorter time. No "fire storm" condition occurred.

3. *Casualties.* An air-raid alarm was sounded at 2020 hours, 5 August 1945, and most of the people fled to the hills, because they had little faith in the inadequate air-raid shelters provided for them. After waiting several hours during which nothing happened, they returned to town. The attack at 0005 hours, 6 August 1945, came without warning because of failure of the warning system; and many persons were trapped and burned. According to police records, 484 persons were killed, and 150 were injured sufficiently to require hospitalization; 430 were burned to death and 54 were killed by fragments; most of the injuries were in the nature of burns.

4. *Fire defense.* Little or no effort was made to combat the fire. The fire-defense organization included 300 volunteer firemen and a detachment of the city police. Since the only fire truck had been destroyed in a previous attack, the majority of the men was organized into bucket brigades. Even if the fire truck had been in operation, it would have had no effect on the results of the attack, since fires were started in hundreds of places in the city at about the same time. The fire was so widespread that the 70 men who reported for duty directed most of their efforts to saving personal belongings or to escaping the area.

VII. Analysis of Damage

1. The M69 incendiary bomb was extremely effective against this target in the concentration obtained. The load carried would have provided a concentration of 500 tons per square mile, if all the bombs had struck within the city. It is estimated, however, that the bombs were dispersed over an area roughly twice this size. In the Kurashiki Cotton Mills area, on the northwestern edge of the city, the concentration was estimated at 200 tons per square mile. But dispersion of bombs is as important as density, and there must be a sufficient number to cause a conflagration over an area large enough to discourage fire fighting. Where single bombs fell on isolated buildings, the residents were able to extinguish the fire before it gained headway. The only unexploded M69 bombs found by the team were 20 of some 1,500 which were estimated by the Japanese to have dropped on the Kurashiki Cotton Mills. These bombs had been placed in a concrete water tank by plant personnel. If there were malfunctioned incendiaries in the city, most of them were probably burned in the fire.

2. Twenty-pound fragmentation bombs and 500-pound general-purpose bombs with air-burst fuzes were used in this attack for antipersonnel effect and to discourage fire fighting. It was not possible to appraise the damage caused by these bombs because evidence thereof had been subsequently obliterated by the fire. Questioning of residents and police indicated that these bombs were treated lightly or ignored by the people in their efforts to extinguish fires or save personal belongings, possibly because they were apparently unaware that these types of bombs were being used. The police said that many of them fell outside the city in the direction of the hills, and most of the casualties occurred when the escaping people ran into this area of burst. They caused no damage to underground utilities, probably because none of the bombs had delay fuzing and consequently did not penetrate the ground. It is believed that this was a result of the air-burst fuze which should have caused the bombs to function at a height of 10 to 40 feet above the ground. Since no 500-pound bomb craters nor unexploded bombs were found, it is assumed that there were probably no malfunctions of this fuze. It is further believed that neither the fragmentation nor the general-purpose bomb contributed to the effectiveness of the attack.

3. Approximately 85 percent of the residential area was destroyed by this attack, leaving about 47,000 persons homeless. This displacement of workers had little effect on production in the remaining undamaged plants because the

people were able to live in the numerous nearby villages and commute to Imabari.

4. Of the 40 plants in the area, 27 were damaged to such an extent that production ceased. A typical plant (Photo 15) was a combustible building containing a moderate amount of combustible material. The M69 incendiary easily penetrated the roofs which were of corrugated asbestos cement on unprotected steel or wood trusses, and, where the concentration of bombs was sufficient to defeat the efforts of the fire fighters, the factory invariably suffered heavy damage. Combustible roofs were burned and asbestos-cement roofs were shattered by the heat, so that weather further damaged machinery in the buildings, most of it beyond repair (Photos 9, 11, and 12). There were many noncombustible-type buildings used to house small iron foundries, machine shops, and cotton mills. Where there was only a small amount of comcombustible material in these plants, there was little structural damage (Photos 8 and 9). The only fire-resistive building in the burned area of Imabari was the post office. This building was subjected to exposure fires but was not structurally damaged, although the contents were burned. Some of the factories were surrounded by high, solid-brick walls with an intervening space of about 5 to 15 feet. These walls were sufficient in several cases to prevent combustible plant buildings from being ignited by exposure fires, probably by directing the flames upward, since there was little wind.

5. In the Kurashiki Cotton Mills, Ltd., a large textile plant partially converted to the manufacture of 13-millimeter machine-gun bullets, a standard American sprinkler system was in service in about half the building area. The buildings in this plant were one story high, and had masonry walls and wood or unprotected steel roof trusses covered with corrugated asbestos cement. The fire areas were segregated by good metal-clad, automatic fire doors which functioned properly. According to the Japanese about 1,500 bombs struck the plant area (700 by 900 feet) setting fire to the buildings and contents. This provided a concentration of about 0.32 ton per acre or 200 tons per square mile. Employees attempted to combat the fires, but soon gave up and fled to safety. The sprinkler system operated, but the drain on the water supply was so severe because of the large number of open heads that the system became useless. Tokyo Cotton Mills, Ltd., a large textile mill located at the mouth of the river bordering the city on the south, had been converted to the manufacture of ailerons. A few bombs fell on the frame hospital at the north side of the plant and destroyed it. The hospital was not close enough to the other buildings to cause an exposure fire and no other part of the plant was damaged. The Ube Cotton Mills, Ltd., and another plant of the Tokyo Cotton Mills were located in the central section of the city, but so few bombs struck the plants that the fires were easily extinguished by the fire fighters and little damage was done. This indicates that the bomb concentration near the aiming point was too low.

6. There were no man-made firebreaks in the city and the streets were so narrow that they were of little or no value for that purpose. In general, the fire burned itself out against open areas, but in some sections it burned itself out in the center of blocks at narrow alleyways. This circumstance may be explained by the almost complete lack of wind necessary to spread the fire and by the fact that the wind which started during the attack was caused by the updraft of the fire and was in the direction of the center of the area.

VIII. Recommendations and Conclusions

1. The bomb load carried against this target was excessive considering the area of the target, and the accuracy of the attack. One-half the load carried, or 250 tons, would probably have been adequate, if the accuracy of the attack had been sufficiently good within the city area.

2. The bomb density on the target was not uniform and better results would have been obtained if such had not been the case.

3. The M69 incendiary was effective against the typical Japanese residences of Imabari and was also effective against the industrial plants with roofs light enough for it to penetrate, whether they were combustible or noncombustible, provided that the noncombustible buildings had a moderately combustible occupancy, and provided further that fires were started in enough places in the plant to discourage the plant fire fighters.

4. Japanese firemen in Imabari were neither well disciplined nor sufficiently trained, and the equipment was totally inadequate, in both quality and number, to deal with the eventualities of an air attack with incendiaries. The water system compared favorably with that of other Japanese cities. The earth-covered, air-raid shelters were useless.

5. The city was extremely vulnerable to incendiary attack because of the high built-upness and combustibility of the buildings and the absence of fire breaks.

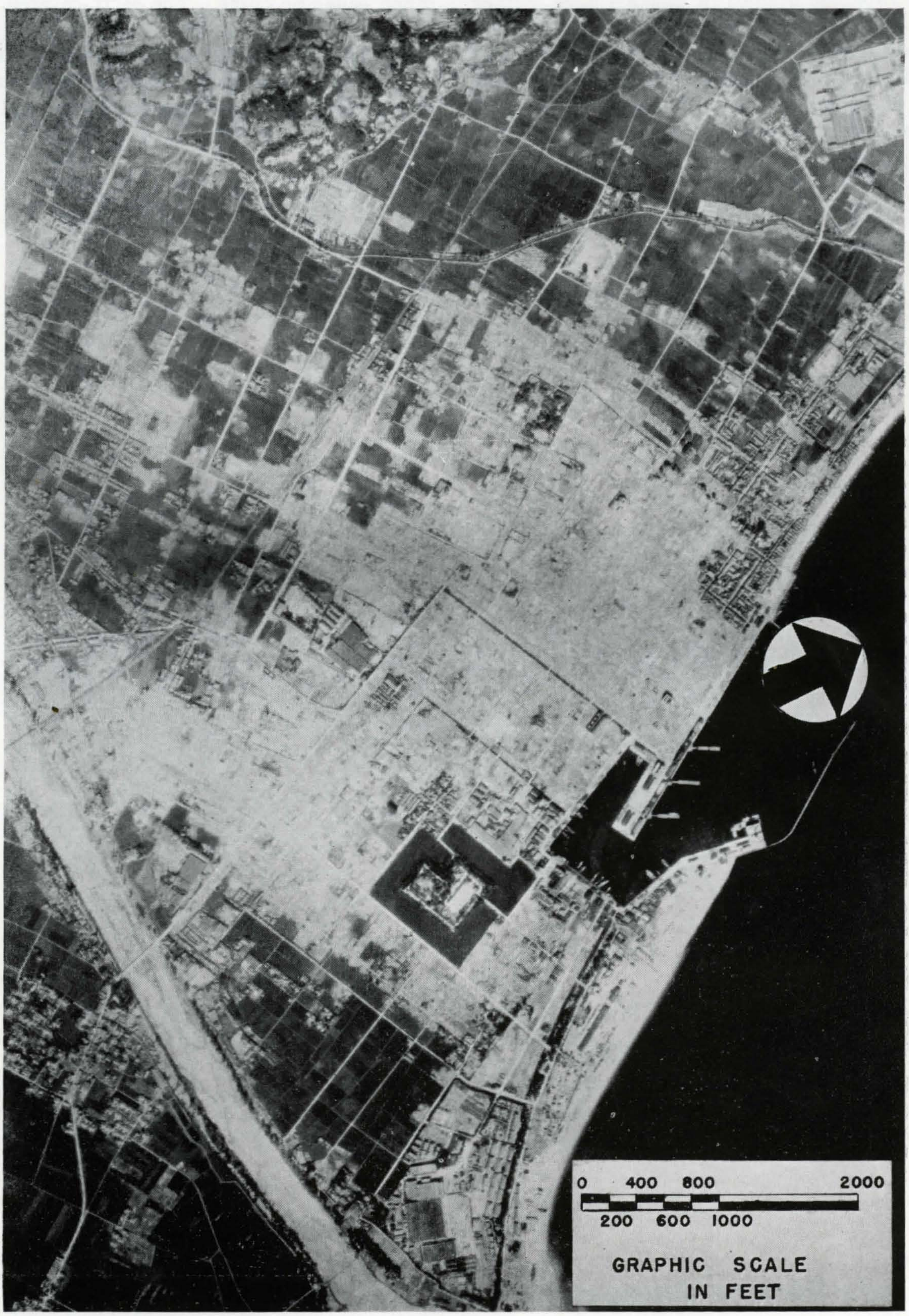


Photo 1.—Post-strike aerial view of Imabari. The light gray area is damaged by fire; the portion in the lower left corner across the river from the city is undamaged.

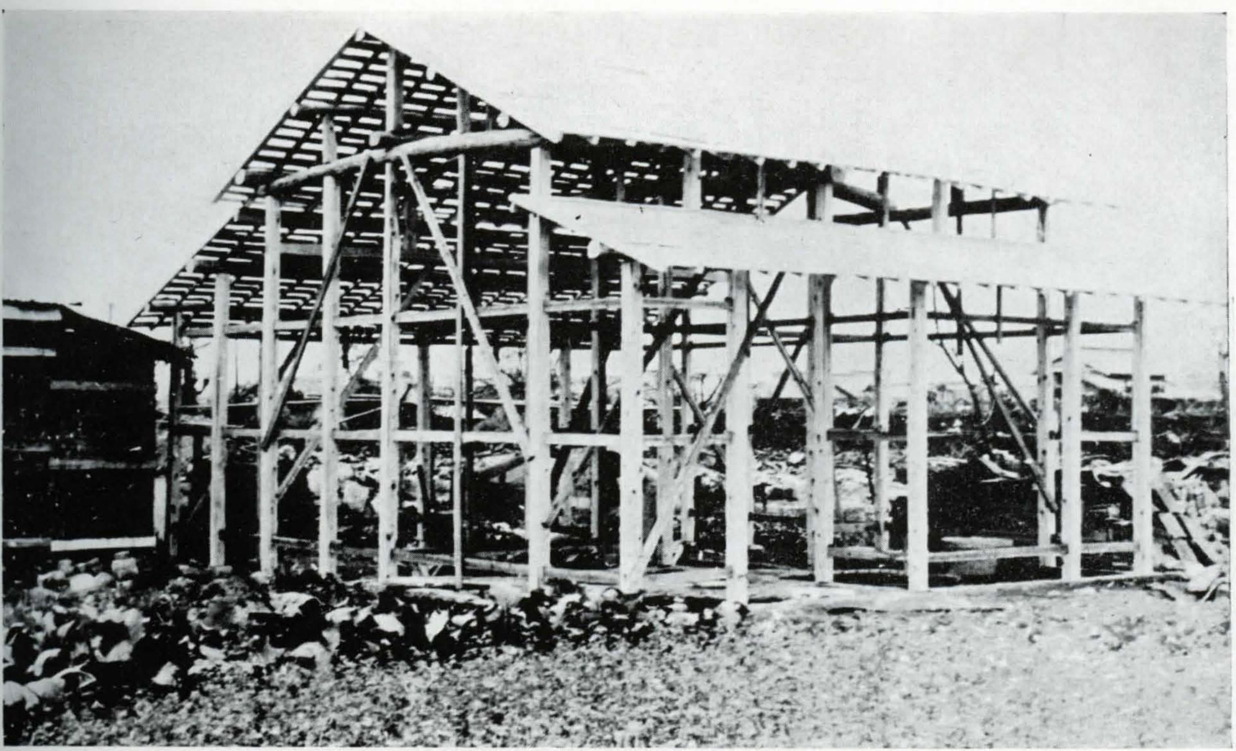


Photo 2. — Partly completed Japanese house showing a typical example of framing. Note the mortise-and-tenon joints.

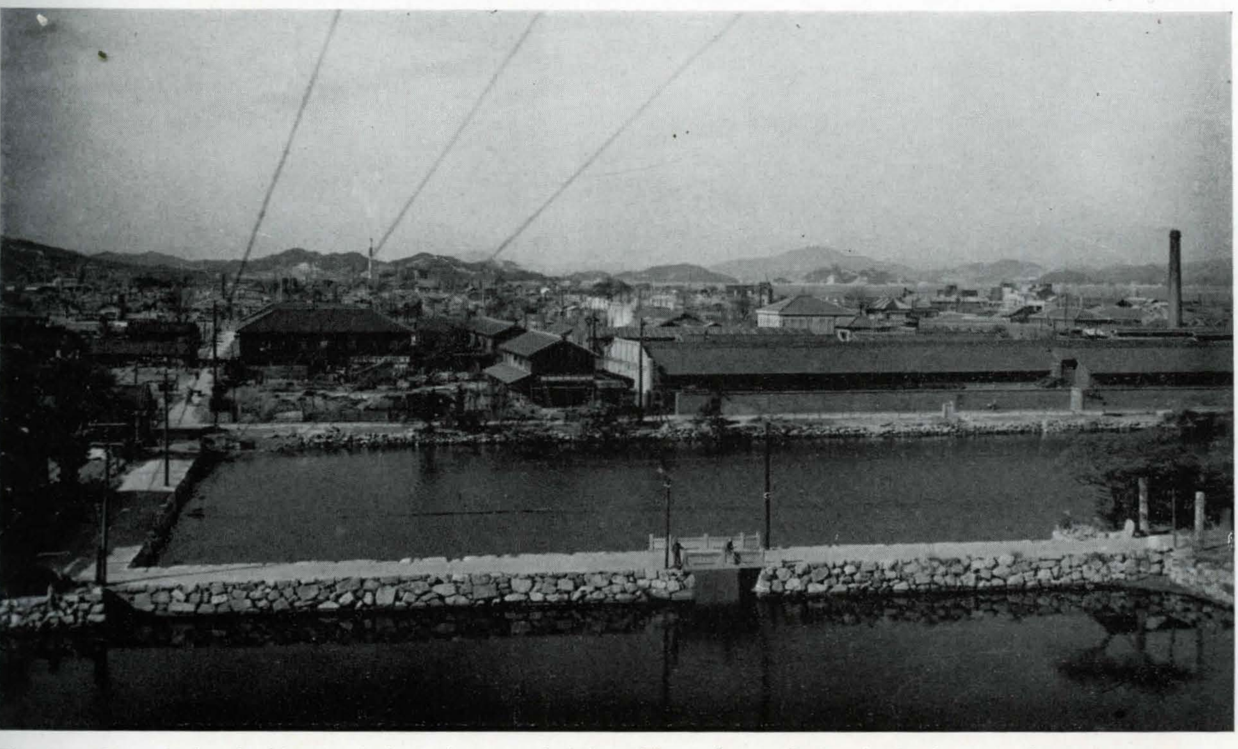


Photo 3.—General view looking north from the moated shrine. The undamaged plant in the foreground was the ABE Cotton Mill, Ltd.

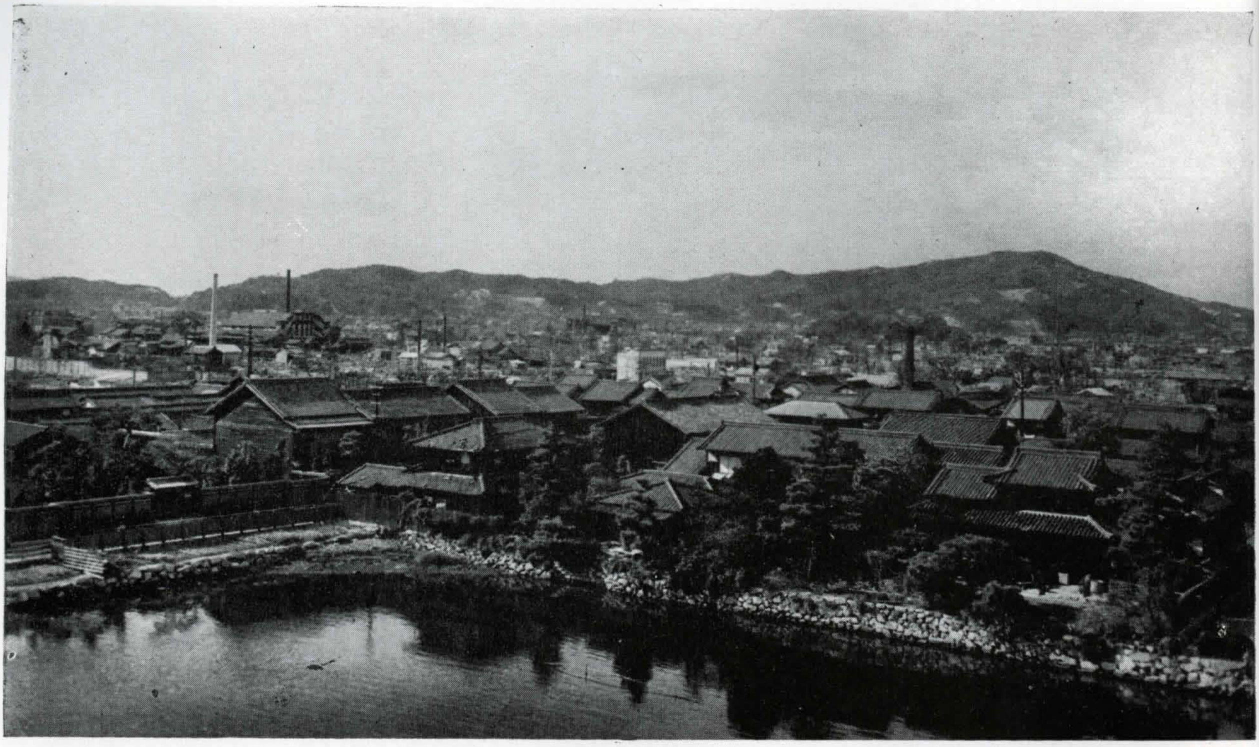


Photo 4.—General view looking NNW from the moated shrine. Note the undamaged dwellings in the foreground. No bombs fell in this section.

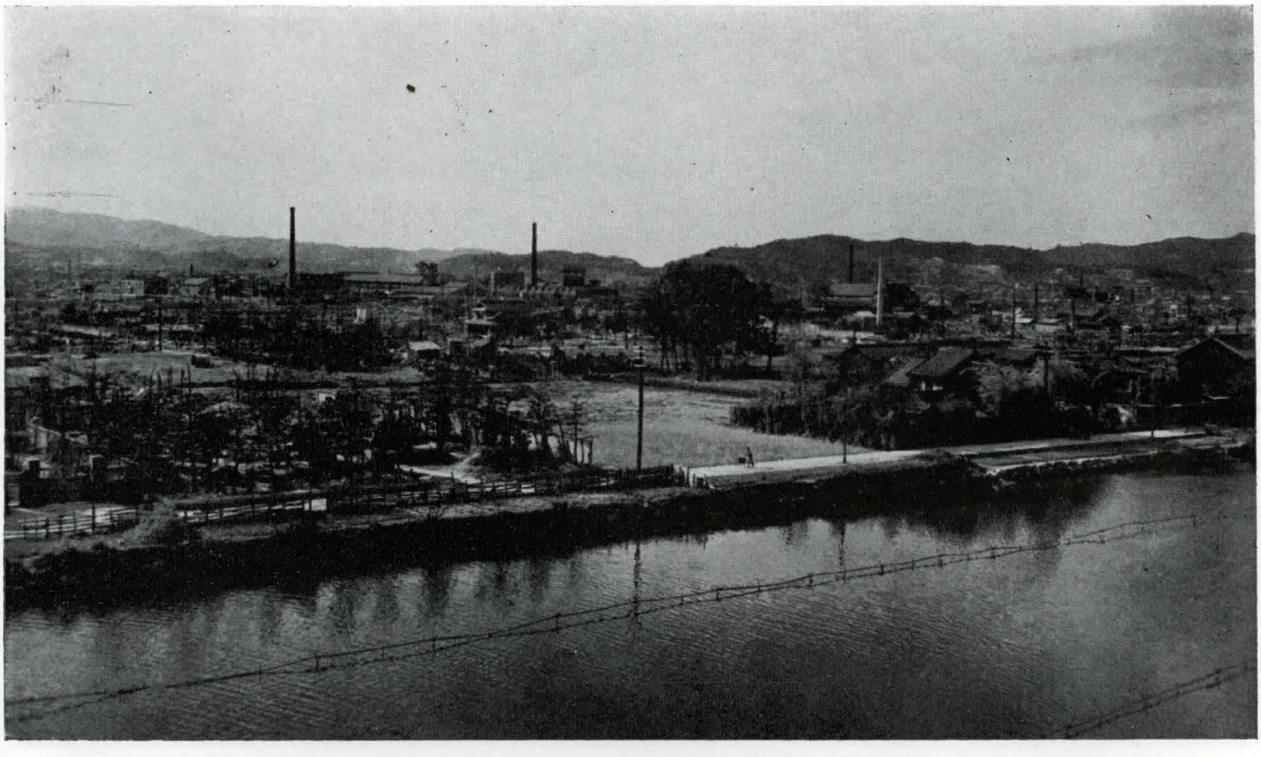


Photo 5.—General view looking west from the moated shrine. Observe the burned dwellings on the left and the intact area on the right.

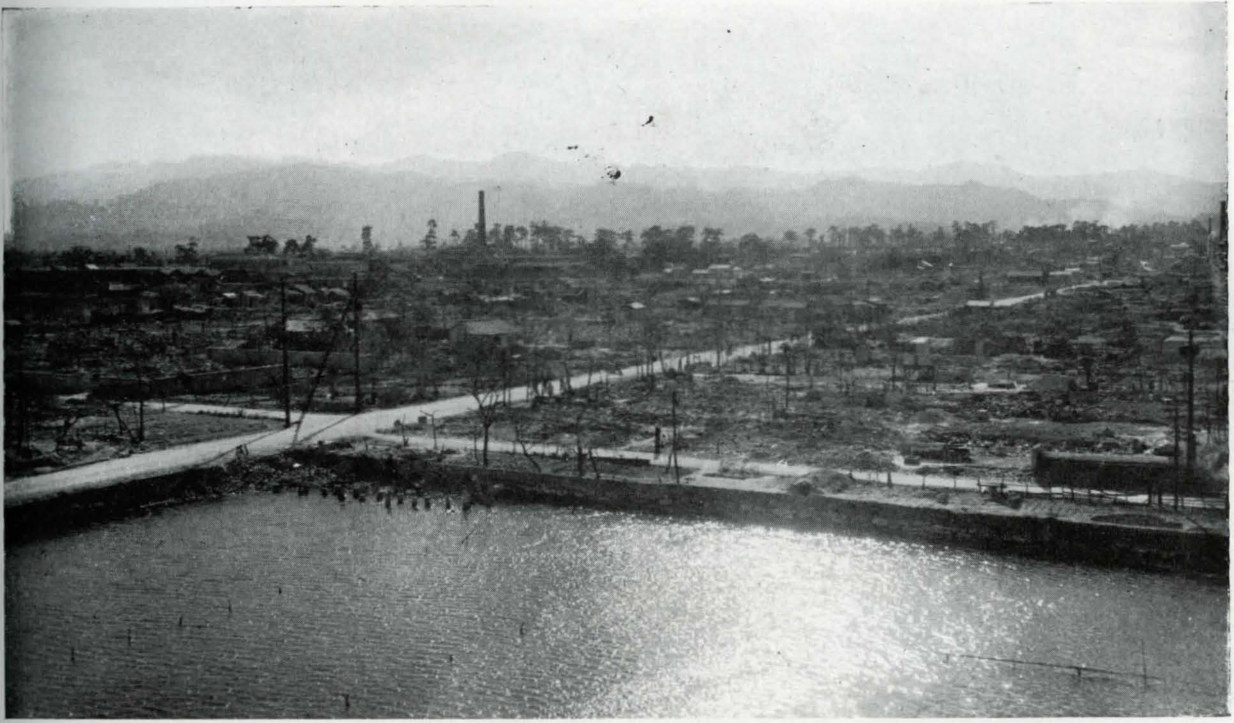


Photo 6.—General view looking SW from moated shrine. See Photo 4 for details of unburned area.

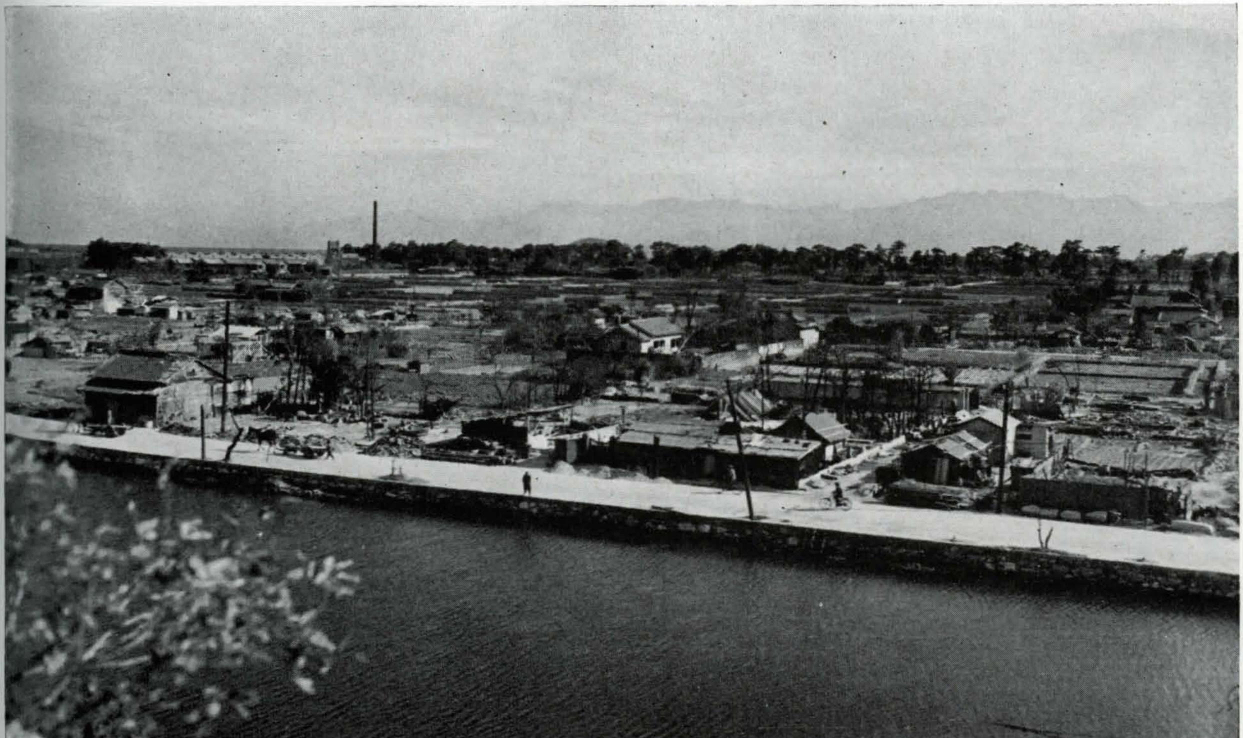


Photo 7.—General view looking south. The plant in the far background is the Tokyo Cotton Mill, Ltd., which was not damaged. The dwellings in the foreground have been rebuilt.

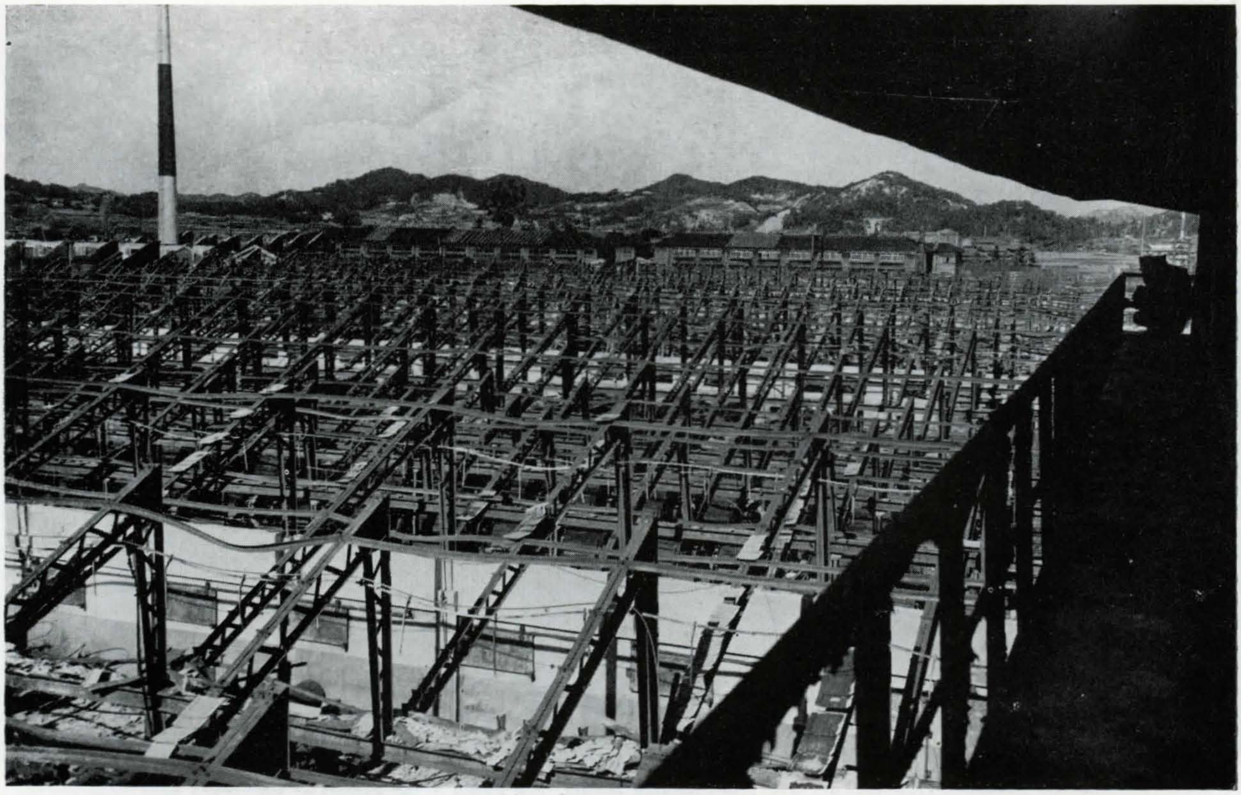


Photo 8.—General view of the Kurashiki Cotton Mill, Ltd. The roof covering for the building in the foreground was asbestos cement.

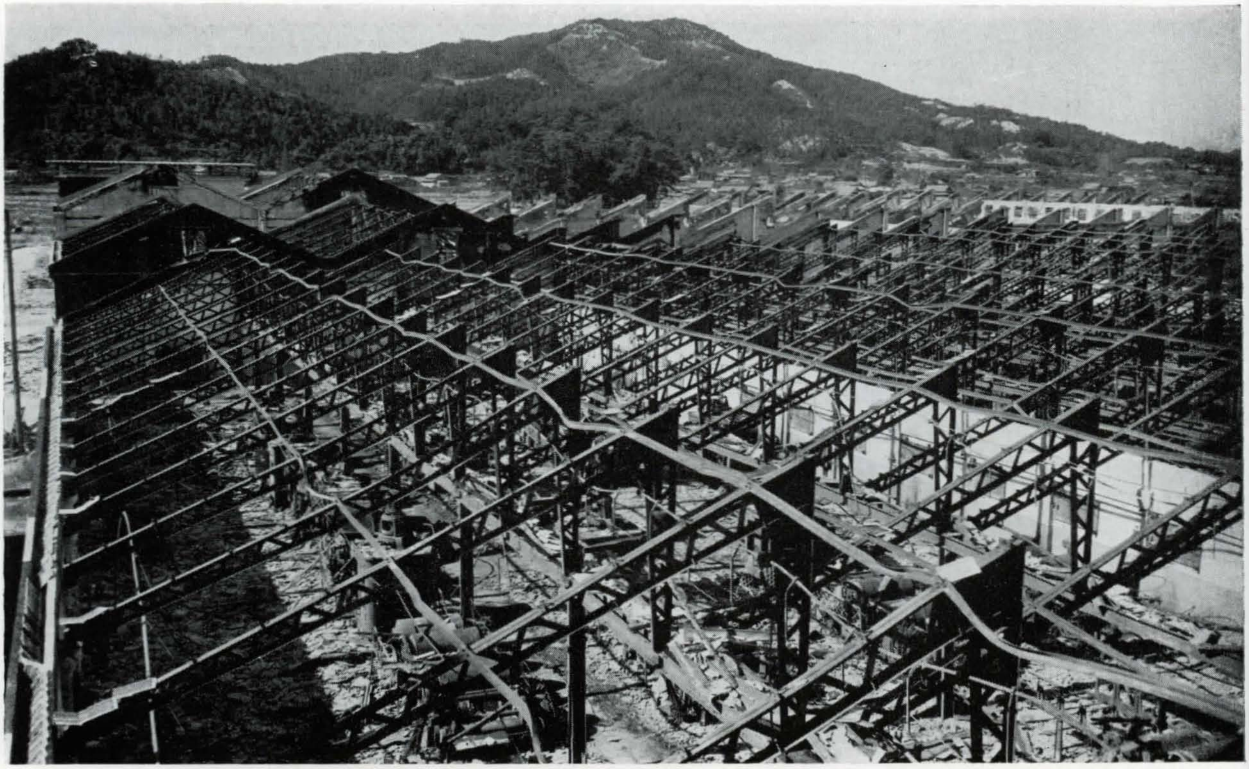


Photo 9.—Kurashiki Cotton Mill, Ltd., carding room. The roof and machinery were damaged, but the roof girders were still usable.

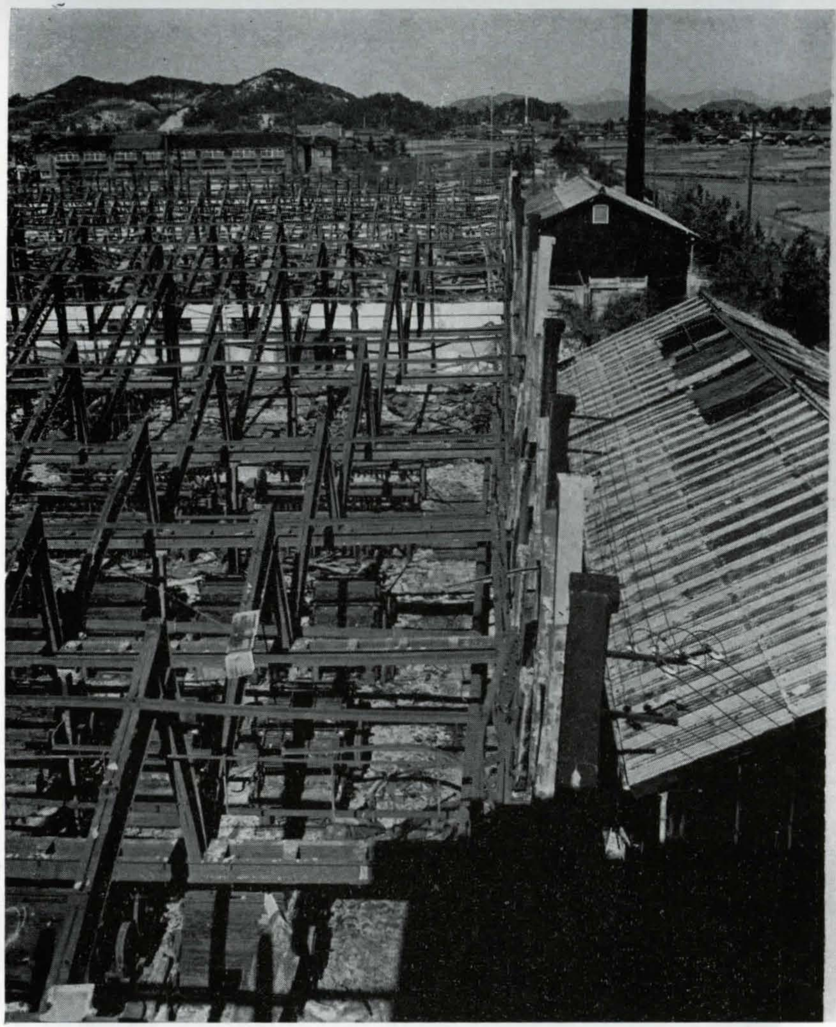


Photo 10.—Kurashiki Cotton Mill, Ltd. Note the distorted wall.

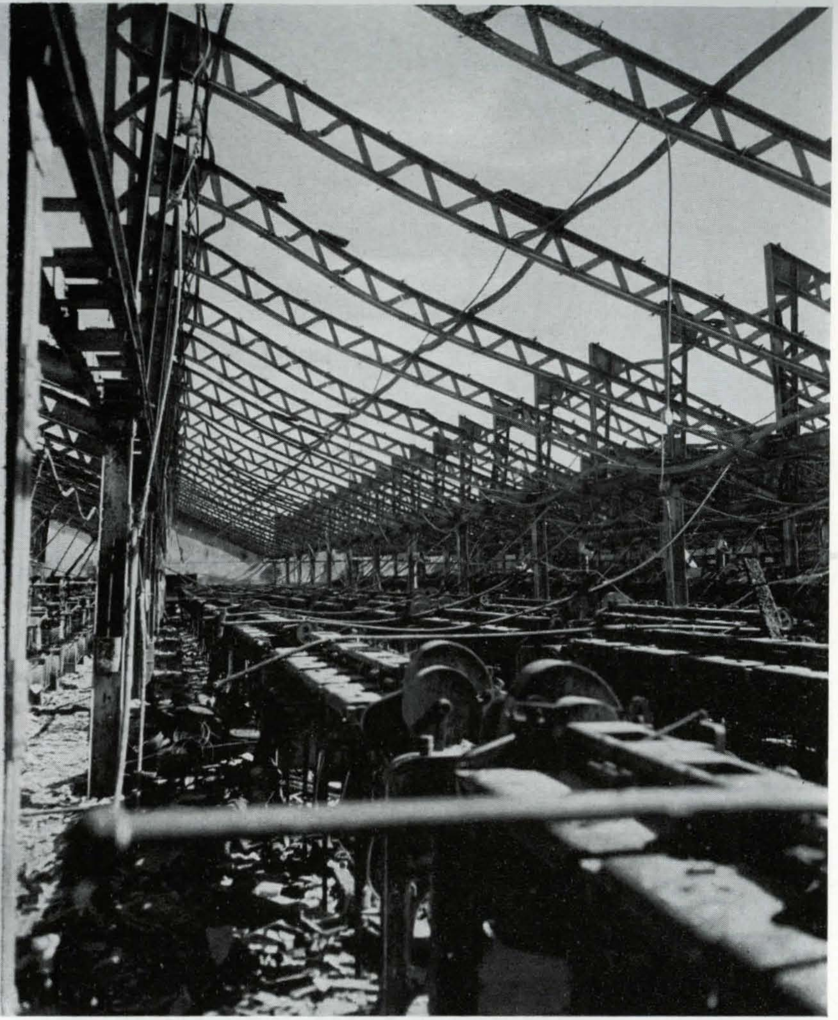


Photo 11.—Spinning room of the Kurashiki Cotton Mill, Ltd. The machinery was damaged severaly by fire and weather. Note the slight deformation of the roof girders in this area.

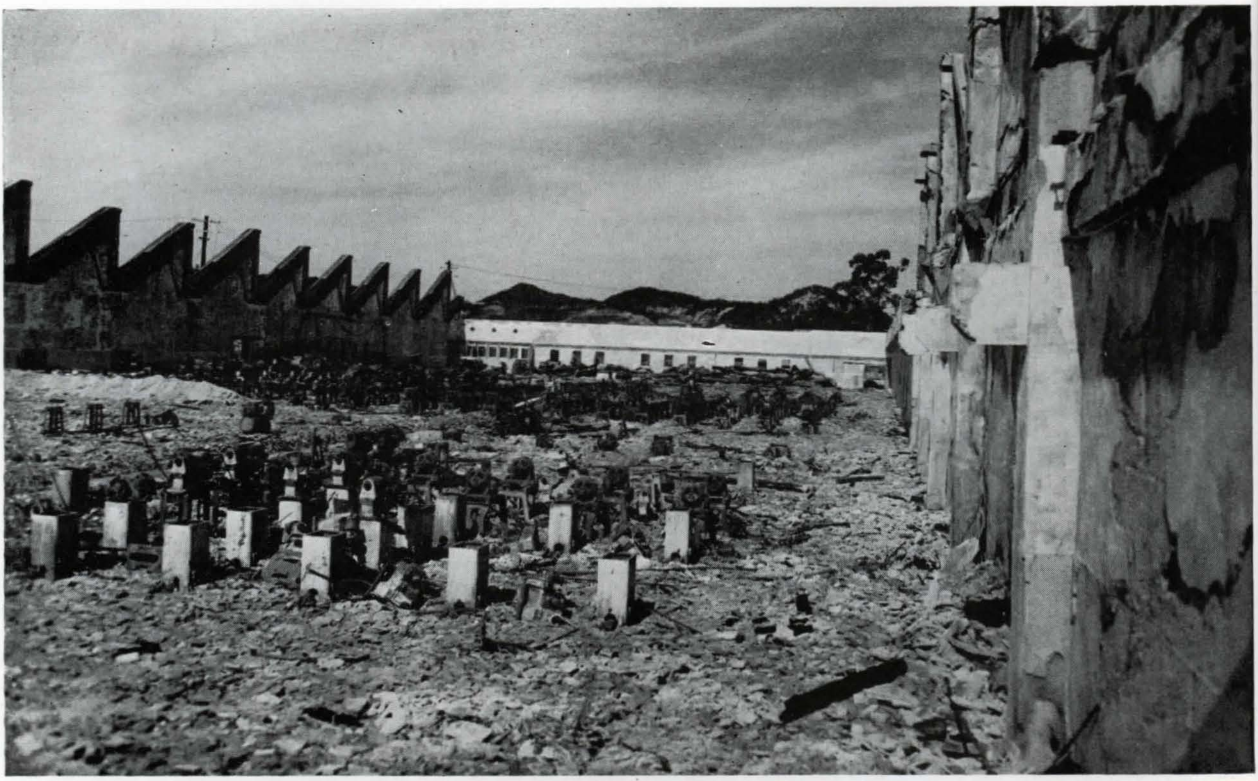


Photo 12.—Kurashiki Cotton Mill, Ltd., area used in making 13-mm. machine gun bullets. The roof was asbestos cement laid on wood saw-tooth roof trusses, supported by wooden columns. The machinery was severely damaged by fire and weather.

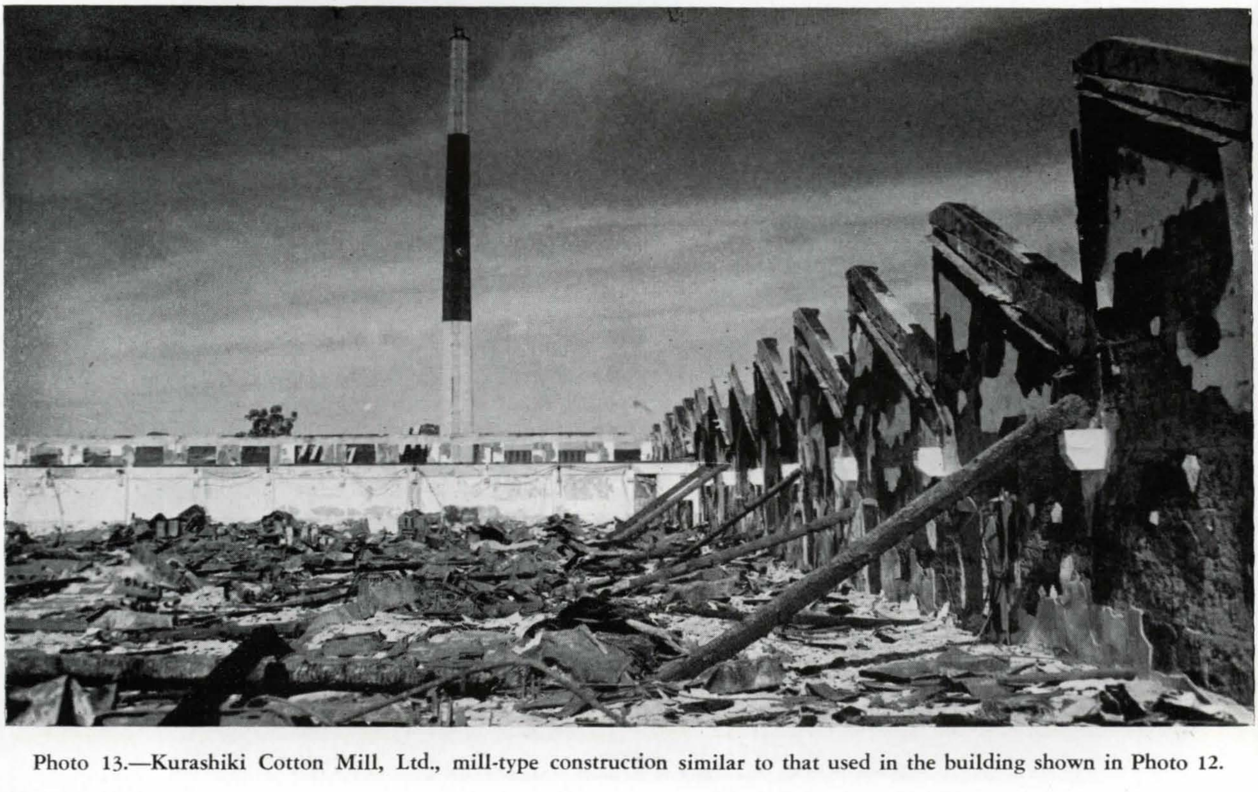


Photo 13.—Kurashiki Cotton Mill, Ltd., mill-type construction similar to that used in the building shown in Photo 12.

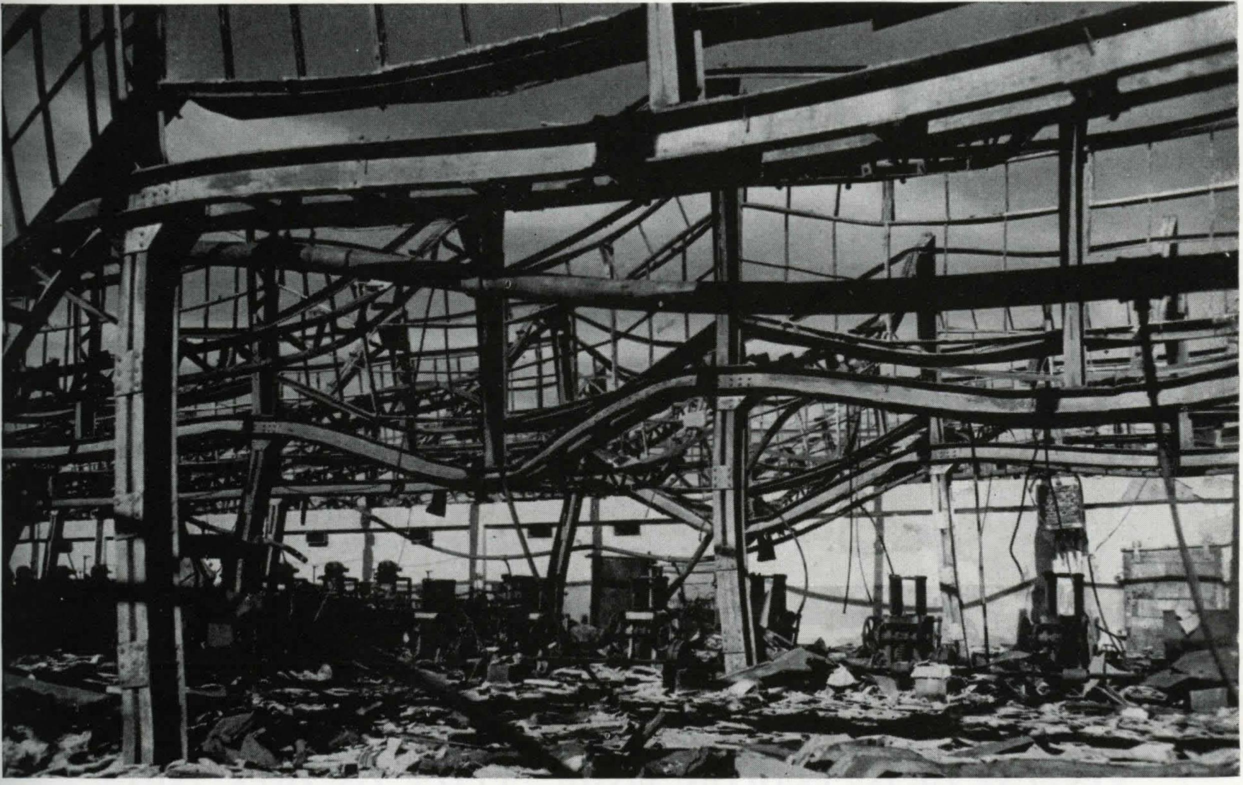


Photo 14.—Baling room, Kurashiki Cotton Mill, Ltd., a severe fire in this area deformed beams and columns. Note the broken and warped sprinkler piping.

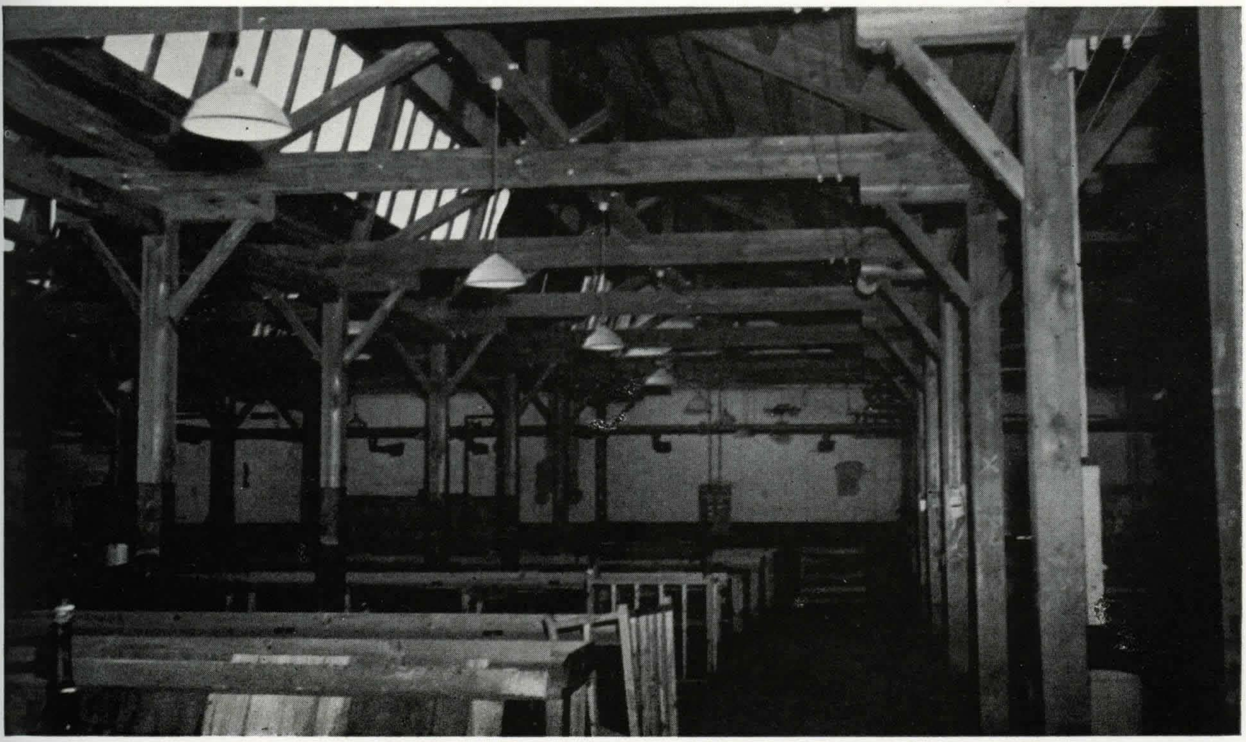


Photo 15.—Typical roof construction used in cotton mills.

Part 2

EFFECTS OF INCENDIARY BOMB ATTACK ON OITA, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 26

II. SUMMARY 26

III. GENERAL INFORMATION 26

IV. THE TARGET 27

V. THE ATTACKS 29

VI. THE FIRE 30

VII. ANALYSIS OF DAMAGE 31

VIII. COMMENTS AND CONCLUSIONS 37

Photographs 1–70, inclusive

Tables 1–5, inclusive

Figures 1 and 2

I. Object of Study

1. The city of Oita, Kyushu, Japan, was selected for a study of the effectiveness of an M47 incendiary-bomb attack.

II. Summary

1. The greater part of the center of the city was heavily built up with typical Japanese one- and two-story wooden structures. A few modern buildings were of reinforced concrete and a considerable number was imitation American and European type with lath and plaster and imitation stone finish, giving them a solid, imposing appearance. Practically every dwelling had electric lighting, but only one percent of the gas consumed in the city was used by householders.

2. Although specific targets in Oita were bombed with high explosives prior to the M47 attack of 16-17 July 1945, and a few M69 bombs were dropped on 10 August 1945, this report deals primarily with the attack of 16-17 July, in which only M47 incendiary bombs were used.

3. The densely built-up area was 0.308 square miles, the sparsely built-up area 1.268 square miles, totalling 1.576 square miles. The total area of the city was 21.7 square miles, of which 7.21 percent was built up. The area destroyed by fire was 0.42 square mile, representing 20.6 percent of the built-up area.

4. For a week prior to the attack there had been considerable rainfall and high humidity. An incendiary attack had been anticipated for some days and, as a result, many women and children were evacuated to the neighboring hills or communities, which accounted somewhat for the low loss of life and few serious injuries.

5. The official Japanese report indicated that the attack began at 0010 and ended at 0135 hours, 17 July 1945. The city was attacked by the 73d Wing of the Twentieth AF. The aiming point was about 1,000 feet west of the prefecture building.

6. A maximum of 790 tons of M47 100-pound incendiaries was dropped on the target. There appeared to be an over concentration in the area west of the main thoroughfare. The bombs did not perforate the roofs of heavy, reinforced-concrete buildings, and burned without damage to those structures.

7. There was one reservoir of small capacity, fed from a river. Failure of electricity precluded use of the pumps, and, in a short time after the start of the attack, the reservoir was three-quarters emptied. Many service pipes in dwellings and commercial buildings melted or were broken, thereby causing an excessive loss of water. Numerous small water containers and a few large static tanks were distributed throughout the city.

8. The fire department and volunteer association fire fighters were unable to cope with the conflagration. Their equipment was antiquated, hose was in poor condition, and direction was inadequate. Bucket brigades were of considerable value in retarding fire spread, and, if more water had been available, would have undoubtedly saved many more buildings.

9. According to the Japanese Air-Defense Diary, some 2,011 buildings burned, 110 buildings were partly burned, and 8,695 persons were made homeless.

10. The city's electrical system was put out of commission because of direct hits on the substation. Poles and wire burned. Even at the time of the survey, some parts of Oita were still without electricity.

III. General Information

1. The following members of P. D. D. Team 2 made the Oita survey:

Maj. C. Ralph Fletcher, officer-in-charge,
Capt. Ving I. Smith, photo interpreter,
Capt. Gerald O. Waeterling, fire engineer,
Lt. Paul M. Speake, U. S. N. R., engineer,
Sgt. A. Hiroshima, interpreter,
Pho M 1/c C. Hovey, photographer.

Capt. F. G. S. Mitchel, RAF, air-raid shelter specialist, accompanied the team to Oita.

2. Information relating to damage to buildings and contents was obtained by field survey. An Army Map Service plan, scale 1/12,500, was used at the time of the survey to check densely and sparsely built-up areas. A Japanese map was obtained on which the damaged areas had been recorded. Both were carefully checked by inspection, and were considered accurate after minor corrections had been made.

3. Many damaged areas had been cleared prior to this survey, and a scrap metal drive, started early in August, included removal of bomb casings from all sites. All malfunction-

ing bombs had been disposed of. No positive information could be obtained from the Japanese relative to the approximate number of bombs dropped or duds found.

4. Following is a list of persons interviewed by team members:

Name and position	*Information obtained on*
Mr. Fuku, Chief, Fire Precaution	Fire department equipment. Fire breaks. Control of fire. Air-raid shelters.
Mr. Yufu, Chief, Air Defense	Air-raid precautionary measures.
Mr. Kurahata, Chief, Public Works	Building codes.
Mr. T. Masuno, Engineer and Interpreter	General data.
Mr. U. Tomogo, Manager Kyushu Electric Supply Co.	Electric light and power.

IV. The Target

1. *Area.* Oita, located on the south shore of the Beppu Wan delta plain in northeast Kyushu, was the largest Kyushu city on the Inland Sea. Its site was flat. The densely built-up area (20 percent or more built up) measured 0.308 square mile; the sparsely built-up area (5 to 20 per cent built up), 1.268 square miles; the total built-up area (5 percent or more built up), 1.576 square miles. The total area of the city was 21.7 square miles, of which 7.21 percent was built up. The area destroyed by fire was 0.42 square mile, representing 26.6 percent of the built-up area.

2. *Importance.* The city was a prefectual capital and a district regimental headquarters. There was a large number of schools and banks. It had no major industry, although textile and sauce factories, together with a vital naval air depot for three Kyushu airfields (Oita, Saeln, Usa), were noted. Rail yards within the area represented an important hub for the Idary line, the East Coast Nippon Main line, the Kyudai line to Kuraine, and the Hobi line to Kumamoto. Oita also had the only important railway repair facilities on the east coast of Kyushu. The town appeared to have been thriving and well organized.

3. *Commercial district.* The main commercial district ran roughly north and south, toward the only railroad station and the freight yards, along a main street which divided the city approximately in two.

4. *Building construction.* The central part of the city was heavily built up with wood dwellings, about 50 percent of which were one story and the remainder one and one-half and two stories in height. The typical Japanese dwelling has four small rooms. Framework was about four by four inches and two by two inches, over which was placed bamboo lath covered with about two inches of mud. Exterior sides were covered with thin boards, often treated with coal tar or oil, rubbed dry. Interiors were generally of smooth finished wood, with paper or cloth insets in sliding doors. Flooring was covered with two-inch, woven, straw matting (Tatami). Ceilings were ¼-inch boards. Roofs were pitched with tiles laid on mud on wood sheathing supported on heavy wood beams, many of which were hand hewn. Footings were of concrete, brick, or stone. Comparatively few dwellings had been built after 1938.

5. *Heating and cooking appliances.* Heating of individual rooms was accomplished by a large brazier, usually glazed porcelain, partly filled with sand and old ashes. Charcoal fires were used, and, occasionally, a small metal plate on six-inch legs was placed over the charcoal to heat water for tea. The kitchen was generally the smallest room. Two types of stoves were used: one, a wood- or coal-fired, metal, "pot"-type appliance, set on the wood flood; the other, a brick-set, open-hearth type, either round or square. Electricity was used in practically every house, but only one percent of the available gas was used for domestic purposes.

6. *Congestion of buildings.* Buildings were detached or contiguous, and some were designed to house two and three families. The absence of masonry fire-division walls was particularly noticeable, and the only considerable separation between buildings was due to the streets, the widths of which were: maximum 30 feet, average 18 feet, minimum 12 feet. The blocks of the residential, as well as the commercial areas, were roughly rectangular, with all thoroughfares running north-south or east-west.

7. *Small stores.* Small stores lined both sides of the main street, and, in addition, were scattered in various districts throughout the

city. They were generally of wood construction and differed little from the dwellings. Living quarters were often located in the rear or above the grade floor. Masonry fire-division walls were not provided. The contents were usually arranged in a haphazard manner, and, in addition to regular stock, the usual accumulation of paper, boxes, straw, and other combustible material was present.

8. *Large stores and office buildings.* Larger stores and some of the office buildings were designed to resemble European and American types. They were constructed of wood framing and lath and plaster, and had an imitation stone finish which gave them a solid and imposing appearance.

9. *Other buildings.* Schools, courthouses and industrial buildings were usually of wood-frame construction and of moderate size. Banks, a department store and a few office buildings were of reinforced-concrete or load-bearing brick-wall construction.

10. *Building and population statistics.* Prefectural records showed Oita to have 12,638 dwellings, 26 schools, 2,500 commercial and 15 industrial buildings. The population was 61,345, of whom 2,585 were engaged in industry, 8,000 in commerce, 5,027 in agriculture, and 1,290 in various governmental capacities.

11. *Electricity* was furnished to the city by the Kyushu Electric Supply Co., Ltd., a privately owned company. Power was supplied by overhead lines from eight hydro stations. Oita had one power station and one substation. The average power generated was 37,136 kw., and the maximum 54,000 kw. Stand-by power was available from the Nippon Power Co., Onagohata Switch House (maximum 44,000 kw.), the Nippon Power Co., Noborio Switch House (maximum 15,000 kw.), or the Kyushu Electric Co., Ltd., Unashima Switch House (10,000 kw.). All power was carried through the city by overhead lines on wood poles. High tension lines coming into the city were carried on steel poles.

12. *Gas* was supplied by the Beppu Gas Co. There were two gas holders, one of 6,000-cubic-feet (170 cubic-meters) and one of 70,630-cubic-feet (2,000 cubic-meters) capacity. Seventy percent of the gas was supplied to industrial and military consumers; 29 percent to commercial consumers; and 1 percent to domestic consumers. It was the practice of the company to shut off gas at the source at the time of air-raid alerts.

13. *Water* was supplied to the city from one reinforced-concrete reservoir of 525,000-gallon capacity. Three electrically driven pumps, each of 75 horsepower, were located at the river, and had a total pumping capacity of 45,000 gallons of water per hour delivered to the reservoir. After water passed through filtration beds, it was fed to the city by gravity. The sizes of the cast-iron pipes ranged from 18 inches to 3½ inches. The average static pressure in the central portion of the city was 50 pounds per square inch. There were neither booster pumps nor a reserve supply.

14. *Hydrants.* Fire hydrant outlets were underground. There was only one two-way, above-ground hydrant in Oita, and it was located near the fire station. A plan showing the reservoir and the layout of the water and hydrant system is shown in Figure 2.

15. *Public fire department.* The fire department in Oita, called the Organization Against Fire Attack, functioned as a partly paid and partly volunteer organization. It was an emergency war substitute for the peace-time fire department. Following is a list of the personnel and equipment:

Members	1,234
Fire stations	9
Motorized combination engines (350 gpm)	8
Hand-drawn, gasoline-driven pumps (200-250 gpm)	9
Hand-operated pumps	13
Sirens and bells	37
Gas masks	385
Fire extinguishers (U. S. type)	None
Feet of 2-inch hose on each pumper	200 to 400
Feet of 2½-inch hose on each pumper	200 to 400

The combination pumpers were 1926, 1930, 1934, 1938 and 1940 models, respectively, and included Dutch Brussea, Nissan, Ford, and Chevrolet makes. The fire-fighting equipment, judged by American standards, was antiquated, and lacked the high standard of maintenance characteristic of fire departments in the United States. Fire hose was patched in many places, and was totally unsatisfactory for effective fire-fighting use.

16. *Volunteer organizations.* The volunteer

associations were controlled by the chief of the police department of the city of Oita, and together they functioned as a civilian-defense group. From the standpoint of fire fighting, the auxiliary police and fire units (Keibodan) were the most important of these volunteer associations. Approximately 40 percent of the personnel of these units was detailed in the fire-fighting arm and served as an auxiliary to the regular fire department. There were 10 principal districts, 109 block associations, and 911 neighborhood defense squads comprising a total of 4,886 members. The prefectural office gave instructions to the leaders of the block associations weekly, and they in turn were charged with the responsibility of instructing the people living within the neighborhood groups on how to combat fires started by various types of incendiary bombs. Each householder was provided with a booklet that explained the types of incendiaries and gave general air-raid precaution instructions.

17. The following equipment was maintained by the volunteer associations, and distributed in the 10 districts:

Gasoline-driven, hand-drawn pumps	8
Hand-operated, hand-drawn pumps	22
Stirrup pumps	104
Hose carts, hand-drawn	17
Usable hose, 2-inch, 60-foot lengths	518
Lengths of suction hose	372

18. *Static water.* Great reliance was placed upon the concrete static-water tanks located throughout the city, which were below ground and varied in capacity from 1,500 to 5,000 gallons. Small concrete tanks with capacities of from 50 to 100 gallons were common in all areas, as were many 28-gallon concrete tanks. It was the responsibility of the neighborhood association members and householders to keep the tanks filled.

19. *Air-raid shelters.* Three underground, concrete shelters were provided, 2 in the central part of the city, with a combined capacity of 250, and 1 private shelter with a capacity of 300 persons. A fourth cave-type shelter with sides and roof of split boards was provided for factory employees on the site of the Fujito Works. Twenty buildings were also utilized as emergency shelters. Some of these buildings were fire resistive; others were of brick load-bearing, dozo, or wood-frame construction. According to the Japanese, they could accommodate 25,800 persons. Many small shelters were located in the residential areas throughout the city. These were principally of the trench type, braced with boards and bamboo, and had an overhead earth covering, 18 to 20 inches in thickness. The wood framework at the entrances was unprotected and exposed to the action of incendiaries. The capacity of each of these small shelters averaged eight persons.

20. *Incendiary fire precautions.* The Japanese government had ordered the removal of ceilings to provide an open space in which to combat roof fires, and the order was carried out. Gates in walls around property were opened upon the sounding of an alert. Instructions had been issued regarding the evacuation of the aged, infirm and children to the hills when danger of an air raid was imminent. Complete black-out was effected upon sounding of air-raid alerts.

21. *Firebreaks.* The prefecture had prepared a plan to create firebreaks, but virtually no progress had been made prior to 16 July 1945. A few natural breaks existed, such as cemeteries, freight yards, shrines, and broad streets. Firebreaks had also been created by the demolition of buildings in previous high-explosive bomb attacks, but debris had not been removed.

V. The Attacks

1. *Minor attacks.* Oita was subjected to several specific target bomb attacks in March, April and May, 1945. The Fifth AF attacked the city on 10 August 1945 in a small incendiary attack which involved the use of M69 bombs and 50-gallon fuel tanks. The Japanese Air-Defense Diary reported that bombs fell between 1109 and 1113 hours. About 100 houses were destroyed, eight persons were killed, and the damage totalled 340,000 square feet. Most of the bombs fell in areas already burned, and no information could be obtained regarding the effectiveness of the 50-gallon fuel tanks.

2. *Main Attack.* The Twentieth AF records show that on Mission 272, on 16-17 July 1945, 129 B-29 planes from the 73d Wing were airborne to bomb Oita as the primary target. Eleven of these acted as pathfinders. The tar-

get was found by planes which dropped 790.4 tons of M47 incendiary bombs over the city. The following data are a condensation from the records of the Twentieth AF:

Mission No.	Date	Air force	Primary target	Aiming point	Planes dispatched	Planes bombing	Sighting		Time (local time)	Altitude *Feet*	Visibility	Bomb type	Tons	No released	Axis of attack	Intervalometer spacing
							Radar	Visual								
272	16-17 July 1945	73d Wing 20th AF.	Oita	058071 (Just southwest of castle.)	129	124	122	2	1512Z 1632Z	10,000 to 11,450.	8/10 to 10/10.	M47	790.4	22,922	210°-250°.	75 ft.

3. *Antiaircraft defenses.* Oita was defended by 19 heavy antiaircraft guns and 54 medium antiaircraft weapons. Although only one searchlight was identified, the estimated number was from two to six. Because of the poor searchlight defense, only inaccurate flak was expected. The planned altitude of 10,000 to 10,800 feet was believed sufficient to render the medium weapons ineffective, and the route was planned to avoid other flak areas. Enemy flak was encountered by approximately 25 percent of the planes, and was reported to be meager, inaccurate, heavy, and medium.

VI. The Fire

1. *Weather.* It seemed desirable to study the official records of the Japanese Meteorological Station at Oita from which Tables 1-4 are extracts. It will be noted that:

a. There had been rainfall in Oita each day from 10 July to 17 July, except 15 July. On the 16th, precipitation had been 1.15 inches, and on the 17th, 0.45 inches.

b. The average temperature on 16 July was 75.79° F., and on 17 July, 80.42° F.

c. On 16 July, at 2200, the wind velocity was nil and at 0200, 17 July, the official bureau record indicated a south wind with a velocity of 4.8 miles per hour. At 0600, the wind shifted to the west with a velocity of 2.6 miles per hour.

d. On the 16th, there was only 0.1 hour of sunshine, and on the 17th there was sunshine for 1.35 hours.

2. *Alert.* The air-defense commander ordered an alert for all civilian-defense groups at 2350, 16 July. Information had been received by him that a large formation of planes was headed for the city. At the same time, he ordered all householders to make preparations for fire fighting, and a few minutes later ordered the populace to take shelter. All fire-fighting equipment was held in readiness, and the personnel was at its posts.

3. *Start of fire.* Planes began dropping bombs on the city at 0010, 17 July, according to the official Japanese Air-Defense Diary. The prefecture office asserted that wood structures located in the highly built-up area just west of the main thoroughfare took fire immediately. Japanese who were interrogated stated that many bombs fell in that area. There were many direct hits and near misses which caused primary fires. The section of the city located east of the main thoroughfare was more sparsely built up, but fires were started there from direct hits and near misses at more widely separated points.

4. *Progress of fire.* The Japanese reported that the planes departed at 0135. By that time, a large number of wooden structures were afire. The high degree of built-upness, the congestion, the combustible nature of the buildings and the lack of firebreaks caused the then well-established fire to spread. The narrow streets offered no protection to buildings unaffected by direct incendiary action. One Japanese stated that a bomb started a fire on one side of an 18-foot street which destroyed several houses. It then jumped across to the opposite side of the street where no bomb had fallen and burned out completely a two-story house, despite the efforts of inhabitants to save it. Flying embers contributed to the spread of fire at the eastern fringes of the city.

5. *Control of fire.* The chief of Air Defense stated that fires were not brought under control until 0700 hours, 17 July. In isolated sections of the city, fires continued to smolder until 18 July.

6. *Action of fire fighters.* The fire department and the volunteer organizations concentrated their activities on the prevention of the spread of fire by utilizing their motorized equipment and hand-drawn motor-driven pumps until the water supply failed. Many men formed bucket brigades and drenched the

outside of buildings with water until the static tanks became empty.

7. *Action of people.* As the fire grew more intense, the people were forced to leave many of the small shelters located adjacent to their homes. In many cases, the wood framework at the entrances to these shelters started to burn. Some flaming buildings collapsed over the shelters. The heat was intense, and the smoke suffocating. Many persons ran through the debris-choked streets to find refuge in shelters outside the burning area, only to move on again as the conflagration progressed. There was considerable disorder and panic among the people, and efforts of the police and the civilian-defense personnel to maintain any semblance of order were fruitless. A few home-owners remained in the fire area, and, as soon as the planes had departed, saved their homes by pulling down flaming sheds and burning parts of adjacent houses. Some of the people who fled to unburned areas assisted in preventing the further spread of fire by co-operating with the fire-fighting organization.

VII. Analysis of Damage

1. *Areas and nature of damage.* The extent of the damage has been indicated on a plan of the city (Figure 1). Inspection of all the damaged areas disclosed that the part of the city west of the main business street had been hit harder than the east side, as it was almost completely burned. Practically every wood building was 100 percent damaged. Only the concrete or stone footings remained, and considerable spalling was noted from intense heat. The few buildings that remained in the devastated area were saved by their occupants.

2. *Causes of damage.* Study of the damaged areas and interrogation indicated that there was an appreciable percentage of primary fires caused by direct incendiary bomb hits and near misses, and the remainder resulted from fire spread. The few natural firebreaks afforded by cemeteries, shrines, roads and structures demolished in previous high-explosive attacks were not effective to any extent in retarding the progress of the fire.

3. *Damage to built-up areas.* The densely built-up area (that is, 20 percent or more built up) was 0.318 square mile, the sparsely built-up area (that is, 5 to 20 percent built up) was 1.27 square miles, making a total built-up area of 1.58 square miles. The area of destruction by fire was 0.42 square mile. The total area of damage was 26.6 percent of the total built-up area. The Municipal Handbook of Japan gave the over-all area (corporation limits) of Oita as 21.7 square miles, so that, accepting this figure as accurate, the city was 7.21 percent built up. The Twentieth AF target area covered 1.4 square miles.

4. *Damage by building classification.* In the burned-out area there were 21 principal buildings or groups of buildings. These have been numbered consecutively, located on Figure 1, and described (together with their damage) in the following paragraphs. Of 15 banks, institutions and public buildings, six combustible and two fire-resistive buildings sustained no damage. Two fire-resistive commercial buildings were partly damaged, and two reinforced-concrete industrial buildings sustained serious internal damage from fire. Table 5 summarizes the damage by classes of buildings.

5. *Building 1.* Fire: Class C; Photo 45.

a. Occupancy. Presbyterian Church.

b. Construction. This building was cross-shaped in plan, 66 by 48 feet over-all, with a plan area of 2,400 square feet; the total floor area was 3,600 square feet. A one-story auditorium occupied the main (south) leg of the cross, with the pastor's study and classrooms in the remainder, which was two story, but of the same height to the eaves—about 20 feet. It was wood frame throughout; the roof was surfaced with asbestos shingles; the exterior walls were covered with stucco; the finished floors were of wood; and the interior wall was surfaced with plaster and wood.

c. Damage. The building lost most of its window glass from blast in high-explosive attacks prior to July. Japanese pulled down burning parts of buildings 10 feet north, and wet down the church walls with buckets of water. The only damage sustained by the building was due to a small eaves fire on the north side, which was extinguished by the bucket brigade.

6. *Building 2.* Fire: Class R; Photo 46.

a. Occupancy. First floor: confectionery manufacture and storage; second floor: living quarters.

b. Construction. Irregular but generally rectangular in plan, this building was 80 by 25 feet over-all; its plan area was 1,800 square feet. The total floor area was 3,600 square feet. There were two stories, and the roof height was 22 feet. It was a reinforced-concrete structure, light, and non-earthquake resistant, with 8- by 8-inch columns carrying the beam-and-slab second floor. The first floor contained no combustible trim or finish materials; the second floor was subdivided by wood-frame partitions and trimmed with wood.

c. Damage. On the second floor all interior partitions and wood trim were burned out, but reconstruction was already in process so that the exact determination of the extent of damage was impossible. The interior finish coat (about 1/8 inch thick) on the concrete walls generally had fallen off. The first floor showed no sign of internal fire. The building was structurally undamaged. Fire destroyed wooden buildings on three sides of this structure, and spread to this building through unprotected openings in the rear.

7. *Building 3.* Fire: Class R; Photo 47.

a. Occupancy. Soya sauce factory.

b. Construction. This was a rectangular, two-story building which was 80 by 48 feet in plan and 26½ feet high. Its plan area was 3,840 square feet, and its total floor area, 7,680 square feet. It had a reinforced-concrete frame with 12- by 12-inch columns. The second floor and roof slabs were divided into bays, 16 by 16 feet. Secondary beams 12 by 13 inches in section and 8 feet o.c. (i.e., on centers) framed into main beams 12 by 20 inches, 16 feet o.c. Beams were slightly haunched at junctions with columns. There were nine-inch brick-panel walls on the exterior, plastered both sides to resemble concrete, and no interior partitions. Windows were unglazed, barred with vertical, square, 2½- by 2½-inch concrete bars 8 inches o.c., and closed by solid wooden shutters on the outside. There had been four skylights or monitors, five by 30 feet in plan, 16 feet on centers.

c. Damage. All window shutters were burned. Skylights were destroyed or removed, and there was evidence (smoked walls, peeled interior plaster) of contents fire. However, no structural damage resulted from fire. At one point, a severe impact on the roof had apparently caused spalling which exposed the reinforcing steel of the underside of the roof slab and one roof beam, but structural failure did not follow. There was no roof perforation, except such as may have occurred through the skylights. Fire was caused either by a direct hit through the skylight or by spread from adjacent buildings.

8. *Building 4.* Fire: Class R; Photo 48.

a. Occupancy. Mercantile shop.

b. Construction. A rectangular two-story building, 22 by 50 feet with a plan area of 1,100 square feet and a total floor area of 2,200 square feet, was 25 feet high to the roof, and had a one-story wing at the rear, 8 by 40 feet. It had reinforced-concrete frame, roof, walls, and floors; columns were 15 by 15 inches, beams were 13 by 21 inches by 22 feet (haunched), 12 feet 6 inches o.c. Walls were 7 inches thick plus finish coats exterior and interior, floor and roof slabs were 5 inches thick. There were no partitions. Openings were in all walls, except the west. Shop front work, sash and frames, stairs, and interior trim were of wood, and there was wood-finish flooring (laid in mastic) on the first floor only.

c. Damage. All woodwork and building contents were consumed by fire; walls and ceilings were damaged by extensive loss of the finish coat; fine cracks appeared in the cement finish of the second floor. There was no structural damage. Fire was caused by direct exposure to fire from adjoining wooden buildings, probably through large window openings on the second floor.

9. *Building 5.* Fire: Class C; Photos 49-51.

a. Occupancy. Bank.

b. Construction. This was an important two-story commercial building, **L**-shaped in plan, 82 by 82 feet over-all, with a plan area of 5,200 square feet, and a total floor area of 10,400 square feet. It was 32 feet high to the eaves and had 17-inch, load-bearing, brick exterior walls and heavy timber interior columns, roof trusses and second floor framing. A small part of the first floor was wood frame, the remainder was concrete on earth fill. The building had wood partitions, probably plastered; steel sash; and slate roofing over wood sheathing, rafters, and purlins. In the internal angle of the building there was a two-story vault which had 23-inch brick walls, a concrete slab overhead, steel vault doors, wood shelving and second floor. A separate record room (outbuilding) in the rear was one story high, 19 by 22 feet in plan, and had 12-inch brick walls and a wood-frame tile roof.

c. Damage. The vault-type doors were badly warped by fire but the vault interior and contents were undamaged. The remainder of the main building was completely burned out, leaving only the exterior walls which were structurally undamaged. The roof and interior of the separate record room were completely burned, only the exterior walls remaining. Direct hits in this building caused the fire.

10. *Building 6.* Fire: Class C; Photo 52.

a. Occupancy. Nippon Savings Bank Co., Ltd.

b. Construction. This small two-story commercial building, 35 by 45 feet, had a plan area of 1,600 square feet, a total floor area of 3,200 square feet, and was 25 feet high to eaves. It had load-bearing brick walls, a slate roof on wood trusses, and wood interior framing and floors.

c. Damage. The building was undamaged. A 12-foot brick fire wall erected about 10 feet north of the building prevented spread from burning wood structures. There was no fire on the side south of this structure.

11. *Building 7.* Fire: Class C; Photo 53.

a. Occupancy. Oita Post Office (postal section).

b. Construction. This was actually two separate buildings, north and south. The north building was rectangular, 25 by 20 feet, had a plan area of 500 square feet, and a total floor area of 1,000 square feet. It was two stories high, had an eaves height of 22 feet and was all of wood construction. The first floor was concrete on earth. Roofing was tile covered, and walls were stucco finished outside, plastered inside. The south building was rectangular, 33 by 22 feet in plan and had a floor area of 700 square feet. It was one story high, had an eaves height of 14 feet, and was of the same construction as the north building.

c. Damage. Both buildings were undamaged. There was no fire in the vicinity on the north side of the north building. Wood structures burned south of the south building, but the fire department prevented spread to the building.

12. *Building 8.* Fire: Class C; Photo 54.

a. Occupancy. Uchida Dispensary.

b. Construction. This commercial building had a main part, 32 by 24 feet, which was 3 stories high, and a rear wing, 22 by 21 feet, which was 2 stories high. The plan area was 1,200 square feet, the total floor area was 3,228 square feet, and the approximate height to the eaves was 30 feet. The building was entirely of wood construction, with walls stuccoed outside and plastered inside. The roofing was of tile. Foundations and the first floor were of concrete.

c. Damage. The building was undamaged. The photograph shows debris of a small burned wood structure on the right but the fire department prevented spread to this building. There was no other fire within 50 feet of this structure.

13. *Building 9.* Fire: Class R; Photo 55.

a. Occupancy. Bank.

b. Construction. This was a two-story building, 28 feet high to the roof, rather irregular in plan but 88 by 44 feet in over-all dimensions, with 2,700 square feet in plan area, and 3,400 square feet of total floor area. Framing, floors, walls, and roof were of reinforced concrete; interior partitions of 4-inch hollow tile or brick, plastered. Interior trim was of wood. All openings on the west and south sides were protected by metal fire shutters or doors.

c. Damage. The rear door on the first floor was warped by fire from the adjacent building and wood trim in that vestibule was slightly burned. The fire did not spread farther into the building as building employees and volunteers extinguished the fire promptly. The building was undamaged structurally.

14. *Building 10.* Fire: Class R; Photo 56.

a. Occupancy. Hypothec Bank of Japan, Ltd., Oita Branch.

b. Construction. Irregular in plan, with over-all dimensions of 180 by 100 feet, this two-story building of 12,400 square feet plan area, total floor area of 24,800 square feet, was modern and was fire and earthquake resistant. Its greatest height to the roof was 36 feet. Frame, walls, floors, and roof were of reinforced concrete; exterior walls were faced with stone; the interior partitions were of 4-inch masonry units and plastered; the interior trim was wood. Roofing was partly tar and gravel, partly cement coating over built-up waterproofing.

c. Damage. Although several incendiary bombs struck the roof, they did not perforate it and caused only superficial damage to the roof fill and surfacing. One bomb that exploded on the ground at the rear of the building broke two wire-glass windows and started a fire in the contents and wood trim of two adjoining rooms on the first floor. The fire was extinguished without serious damage and the building was structurally undamaged.

15. *Building 11.* Fire: Class C; Photo 57.

a. Occupancy. Oita Occupation Group Headquarters (former occupancy unknown).

b. Construction. This building was **L**-shaped in plan, 70 by 94 feet over-all, 4,850 square feet in plan area, and had a total floor area of 9,700 square feet. It was 2-storied, 26 feet high to the eaves, and had 2 small one-story additions at the rear. Load-bearing brick walls, 17-inch exterior and 13-inch interior, supported the wood-frame floors and wood-trussed roof, the latter being surfaced with slate. Walls were stuccoed outside, plastered inside, and interior trim, doors, and the like were of wood.

c. Damage. The building was undamaged. The nearest fire was in a small wood building located 35 feet south which burned but volunteer fire fighters, aided by a 30-foot street which intervened, brought the fire under control.

16. *Building 12.* Fire: Class C; Photo 58.

a. Occupancy. Oita prefectural offices.

b. Construction. This two-story and part-basement public building (33 feet high to the eaves) was rectangular, 190 by 150 feet, and contained two light courts. The net plan area was 21,400 square feet, and the total floor area was 43,800 square feet. All of the walls were of brick, and load bearing; the exterior and fire walls were 17 inches thick, the other interior walls 13 inches thick. Exterior walls were faced with granite up to the first-floor window sills, above which they were stuccoed, and had granite trim. Corridor floors were of reinforced concrete, others were of wood framing and finish. Roofing was clay tile over wood sheathing and framing. The basement extended under part of the building only.

c. Damage. Severe internal fire in the southeast part of the building completely destroyed 30 percent of the roof, 22 percent of the second floor, and 15 percent of the first floor, with additional damage to windows and interior finish in adjacent spaces. There was no basement under this part of the building. All walls remained standing without structural damage. A fire wall with protected openings stopped the fire in one direction, and an interior wall without openings stopped it in the others. This fire was caused by direct hits in the damaged parts of the building.

17. *Building 13.* Fire: Class C; Photo 59.

a. Occupancy. Bank.

b. Construction. This building, 55 by 30 feet, with a plan area of 1,650 square feet, and a total floor area of 3,300 square feet, was a rectangular 2-story structure about 20 feet high to the eaves. It was framed throughout in wood, but was finished on the outside in an excellently executed imitation-stone stucco on wood lath. The roof was tile on wood trusses.

c. Damage. There was no fire in the immediate neighborhood of this building, which was undamaged from that source. Bomb fragments from a previous high-explosive attack did slight damage—perforation of windows, roof, and ceiling, and one hole in the east wall.

18. *Building 14.* Fire: Class R; Photo 60.

a. Occupancy. Department store, first two floors temporarily occupied by the telegraph section of the Oita Post Office.

b. Construction. Basically rectangular in plan, with an offset on one side, this building was 120 by 90 feet over-all and contained 10,000 square feet of plan area, and 45,000 square feet of floor area. It had four full stories and a part fifth story which opened on a roof garden formerly containing two or three small native-style pavilions or other garden structures. Except for these wooden pavilions, it was a thoroughly modern, fire-resistive and earthquake-resistant structure of reinforced-concrete frame, walls, floors and roof. The few interior partitions were plastered and appeared to be of four-inch masonry units.

c. Damage. Fire on the roof, caused by a direct hit, entirely consumed the garden structures and spread through wide openings into the fifth story, burning out the contents and wood trim. The third and fourth stories suffered smoke and water damage to walls, ceilings and contents. A few window lights were missing. Otherwise the building was undamaged.

19. *Building 15.* Fire: Class C; Photo 61.

a. Occupancy. Formerly refectory of the Oita Godo Bank; now converted to banking offices (Building 16).

b. Construction. Actually 3 buildings: (*a*) a **T**-shaped structure 65 by 65 feet over-all, partly 2-story, 1,800 square feet in plan area, 3,600 square feet in floor area, and partly a 1-story section of 1,300 square feet floor and plan area, 20 feet high to the main eaves; (*b*) a rectangular 2-story structure 40 by 22 feet, 900 square feet plan area, and 1,800 square feet total floor area, 18 feet high; and (*c*) a rectangular 2-story record room about 20 by 50 feet, with 1,000 square feet of plan area and 2,000 square feet of total floor area, 18 feet high. All 3 were similar in construction, with 13-inch brick exterior walls (load-bearing), stuccoed outside and plastered inside. Roofing was tile on wood trusses, and internal framing and finish were of wood.

c. Damage. Roof and windows suffered about five percent minor damage from fire, which also very slightly damaged the interior finish. The fire was extinguished without other damage to the building. About 10 percent damage occurred to contents. The fire was caused when burning embers and heat from the adjoining building ignited the roof and window frames. The fire was extinguished by the fire department.

20. *Building 16.* Fire: Class C; Photos 62, 64 and 65.

a. Occupancy. Oita Godo Bank, head office.

b. Construction. **L**-shaped in plan, the building fronted on two streets. This important two-story bank building was 30 feet high to the eaves and 86 by 119 feet over-all. It had 6,700 square feet of plan area, 13,400 square feet of total floor area. Load-bearing brick walls (24- and 29-inch exterior, 18-inch interior) supported interior wood floor framing, except that in the main banking room there were five non-fireproofed columns built up of riveted steel angles carrying steel girders which in turn supported part of the second floor framing. Roofing was of slate and copper over all-wood construction. A small part of the first floor was of cement topping over brick arches; the remainder was wood-frame on brick piers. The interior finish was of wood and plaster.

c. Damage. Except for the brickwork which was undamaged structurally, the building was entirely destroyed by fire; all wood-work was consumed, steel work was distorted, and plaster was burned off the brickwork. The fire was caused by an unknown number of direct hits on the building.

21. *Building 17.* Fire: Class R; Photo 66.

a. Occupancy. Telephone company offices and exchange.

b. Construction. This building was rectangular, 114 by 104 feet, with a central light court, and covered a net plan area of 9,600 square feet, with a total floor area of 19,200 square feet. It was two stories, or about 30 feet high. The building was of thoroughly modern fire- and earthquake-resistive construction throughout, with reinforced-concrete frame, walls, floors and roof.

c. Damage. There was no fire within 100 feet of this building and it was undamaged.

22. *Building 18.* Fire: Class C; Photo 67.

a. Occupancy. Dai Ichi Mutual Life Insurance Co., Oita Branch.

b. Construction. This was a small rectangular office building 40 by 30 feet, with a plan area of 1,200 square feet, and a total floor area of 2,400 square feet. It was two stories high, and was 28 feet to the eaves. It was wood-frame throughout, on concrete foundations. The first floor was concrete. Exterior walls were stuccoed, and interior finish was of plaster with wood trim and doors. The roof was tile covered, on wood boards supported on wood trusses.

c. Damage. The building was undamaged, although fire destroyed a small wood structure located about 20 feet away as shown on the photograph. Volunteers used buckets of water to prevent fire spread.

23. *Building 19.* Fire: Class R; Photo 63.

a. Occupancy. Oita police station.

b. Construction. This was a 2-story building, generally rectangular, 80 by 46 feet overall, of 3,400 square feet net plan area, and 6,800 square feet total floor area. The building was 32 feet high to the roof. It had reinforced-concrete frame, walls, floors, and roof. Partitions were plastered masonry units.

c. Damage. There was no fire within 100 feet of this building and it was undamaged.

24. *Building 20.* Fire: Class C.

a. Occupancy. Grade school.

b. Construction. A group of one- and two-story buildings, of all-wood construction, located in the southwesterly part of the city. High explosives had badly damaged all of these buildings except the three which are the only ones considered in this report because of their having been damaged by fire. They had a plan area of 15,000 square feet and a total floor area of about 25,000 square feet.

c. Damage. The three buildings and their contents were completely destroyed by fire, only the concrete footings remaining. The fire was caused by direct hits on the buildings.

25. *Building 21.* Fire: Class C.

a. Occupancy. Girls' school.

b. Construction. This was a group of 10 main buildings, located near the center of the city, east of the main business street. All of the buildings were of wood construction, principally one-story high. The plan area was 42,000 square feet, and the total floor area was 50,000 square feet. The roofs were tile on wood.

c. Damage. All of the buildings and their contents were completely destroyed by fire, only the concrete footings remaining. The fire was caused by direct hits on some of the buildings and fire spread to the others.

26. *Damage to the electrical system.* The city's electrical system was completely disrupted by the action of incendiary bombs, and by direct hits on the substation. Some of the overhead trolley contact lines were damaged. Street cars did not run until about 1800 hours, 17 July. Light poles were burned, also service lines. Transformers burned out. The distribution equipment was damaged to the amount of 195,253 yen. Damage to high and low tension lines, poles, transformers and their bases, switches, service wire, meters, and all associated electrical equipment amounted to 278,000 yen. In all, 150 poles, 22.5 miles (36 km.) of wire, 90 transformers (900 kva. each) and 17 pull switches were destroyed by fire and debris. These figures and the data relating to the electrical equipment damage were obtained from the manager of the Kyushu Electric Supply Co. At the time this survey was conducted, some areas were still without light.

27. *Damage to gas supply.* The gas mains were not damaged as the result of the attack, nor were the gas holders. Inasmuch as most of the dwellings and small stores were not piped for gas, the damage to service lines leading into buildings was small. Gas was shut off at the source at the time of the alert.

28. *Damage to water system.* There was no damage to the water mains. However, many of the lead-in pipes to consumers' buildings melted or were broken. It was estimated by the Japanese that a 65 percent leakage of water resulted from these breaks in the house service connections. This condition contributed materially to the rapidity with which the reservoir was emptied.

29. *Effectiveness of water supply.* The public water supply failed. The Chief of Air Defense stated that at 0300 hours, 17 July, three-quarters of the water in the reservoir had been used. The electric substation was hit by incendiaries and the pumps at the river, which were electrically driven, were rendered inoperative. The water supply was shut off at the source between 0300 and 0400, 17 July, as the reservoir was low, pressure was fading, and the Japanese claimed there was danger of drawing air into the water mains.

30. *Effectiveness of hydrants.* Recessed hydrants created a problem for the fire fighters. Many of the hydrant covers had been covered with debris, and could not readily be located. Others were under piles of burning material, and were rendered inaccessible.

31. *Effectiveness of fire fighters.* The fire department and volunteer organization were

unable to cope with the conflagration. Antiquated and poorly maintained equipment, poor quality hose, lack of water, and low pressure were the contributing factors. The personnel were not too well directed. In one instance, a group of fire fighters was ordered from its own area, which was later reduced to ashes, to fight elsewhere. Bucket brigades that used water from many small water containers and static tanks were more effective in their efforts to retard the spread of fire.

32. *Value of Air-Raid Shelters.* Many small air-raid shelters were partly burned, several burned entirely and collapsed, and, in many cases, fire attacked the wood framework at the entrances.

33. *Photo Intelligence Check.* The Twentieth AF photo interpretation report on Oita gave the following figures for the attack of 16-17 July 1945:

	Undamaged *(sq mi)*	Damaged	
		(Sq mi)	*(Percent)*
Built-up area (urban)	2.05	0.539	26.8
Built-up area (industrial)	0.156	0.015	9.6
Built-up area (total)	2.206	0.554	25.2

The United States Strategic Bombing Survey found 0.42 square mile destroyed in this attack. A difference in the figures for the built-up portion of the city exists, based on an Army Map Service plan, scale 1/12,500, which gave 1.576 square miles, compared with 2.206 reported by the Twentieth AF. The Army Service plan was found to be somewhat out of date, and the area measured may not have been correctly defined. All industrial areas were excluded in the measuring operation.

VIII. Comments and Conclusions

1. The completeness of the damage inflicted on Oita by the M47 incendiary attack, 16-17 July 1945, suggests an excessive concentration of bombs in the area just west of the main business thoroughfare and west of the aiming point (Figure 1).

2. The M47 incendiary bomb was considered an excellent fire raiser in combustible buildings.

3. Bombs did not perforate heavy reinforced-concrete roofs of multi-storied buildings.

4. Only one M47 malfunction was found.

5. A strong water supply, together with gasoline-driven auxiliary pumps, in addition to the electrically-driven pumps located at the river, might have enabled fire fighters to combat spreading fire more effectively. Modern motorized equipment, good hose, mobile gasoline-driven pumps, and portable hand pumps would have aided firemen in their efforts to save property on the fringe only.

6. Good organization, training and direction of those engaged in fire fighting, coupled with good equipment would have minimized the damage, particularly in the area east of the main business street where the concentration of incendiaries appeared to have been relatively light.

7. The erection of good masonry fire-division walls between wood commercial buildings, and separation walls of a similar type between small groups of wood dwellings might have had a limiting effect on fire spread.

8. The use of wood framing for air-raid shelters is undesirable as shown by the many burned shelters in Oita.

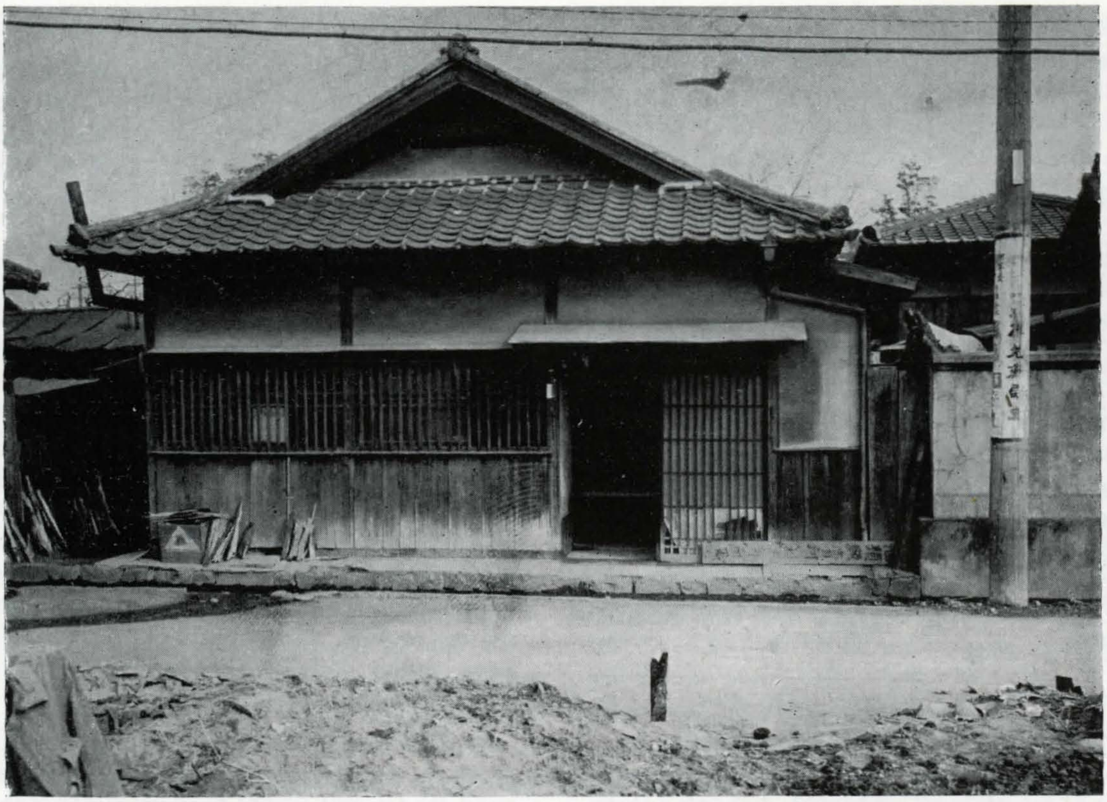


Photo 1.—Typical Japanese dwelling.

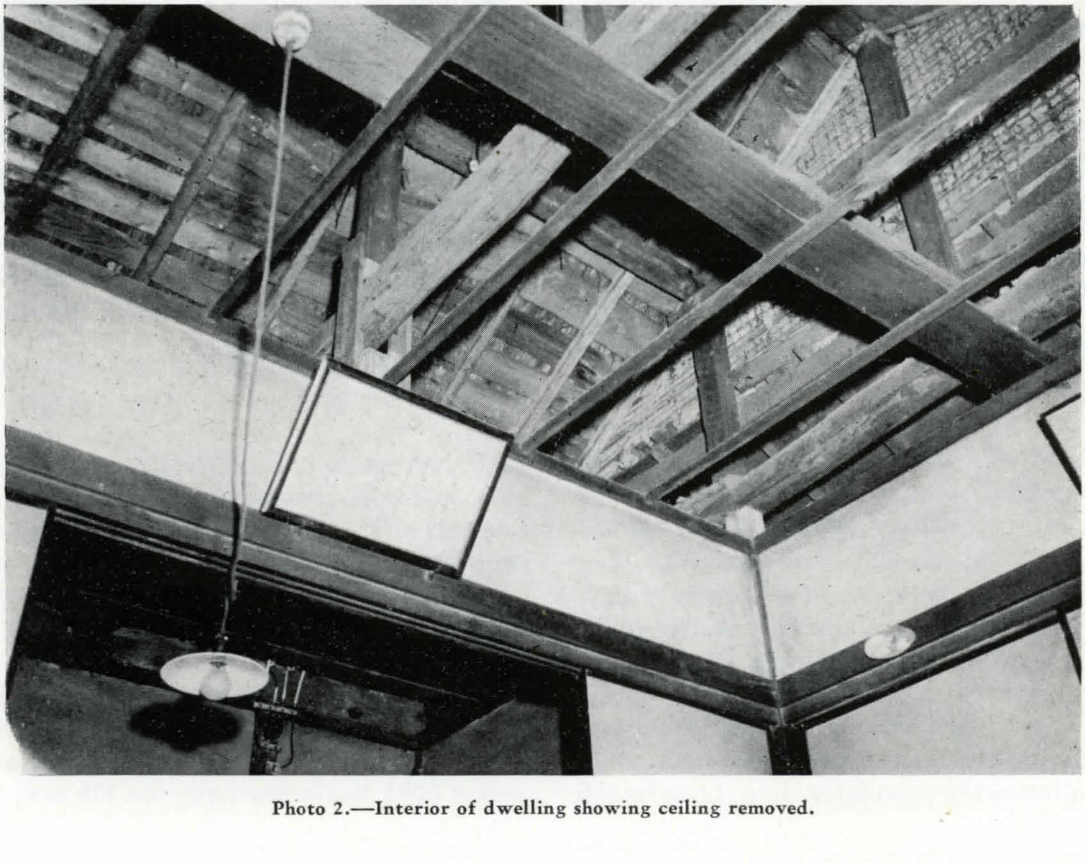


Photo 2.—Interior of dwelling showing ceiling removed.

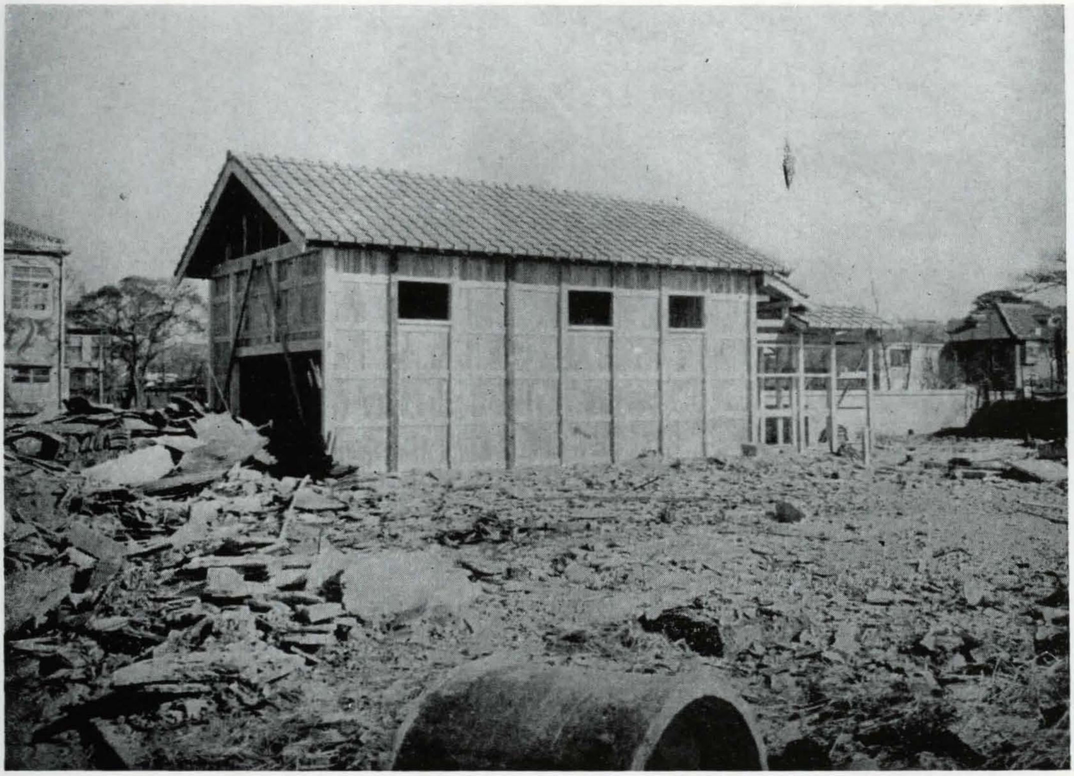


Photo 3. — Small commercial-type structure in course of construction.

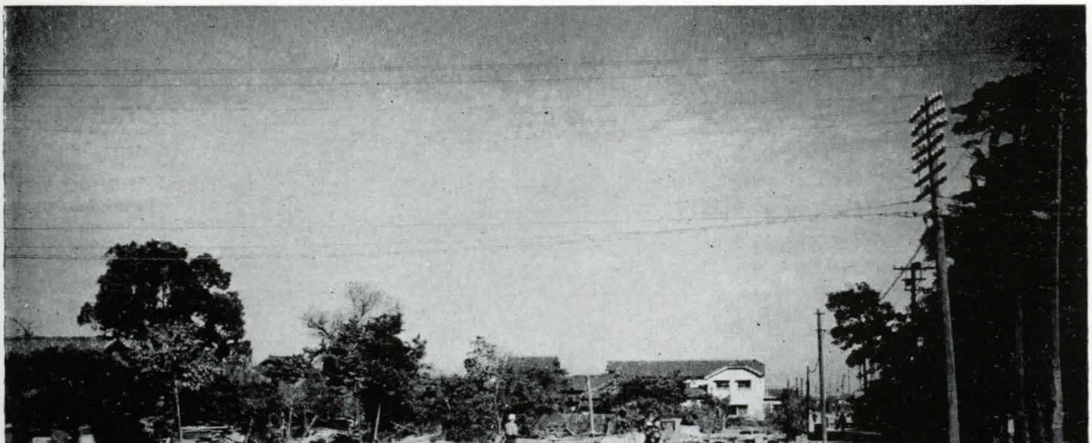


Photo 4. — Firebreak established by HE prior to 17 July 1945. Combustible debhis had not been removed.

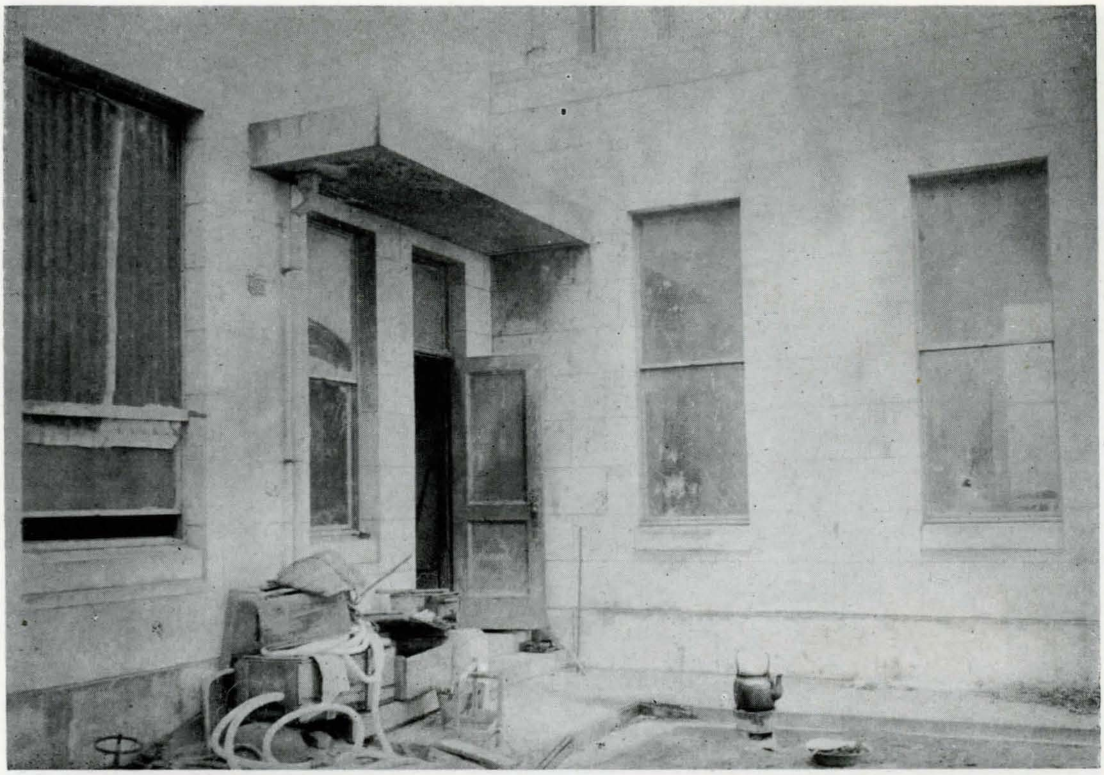


Photo 5.—Wire-glass windows broken by casing fragment resulting in fire in one room first floor back.

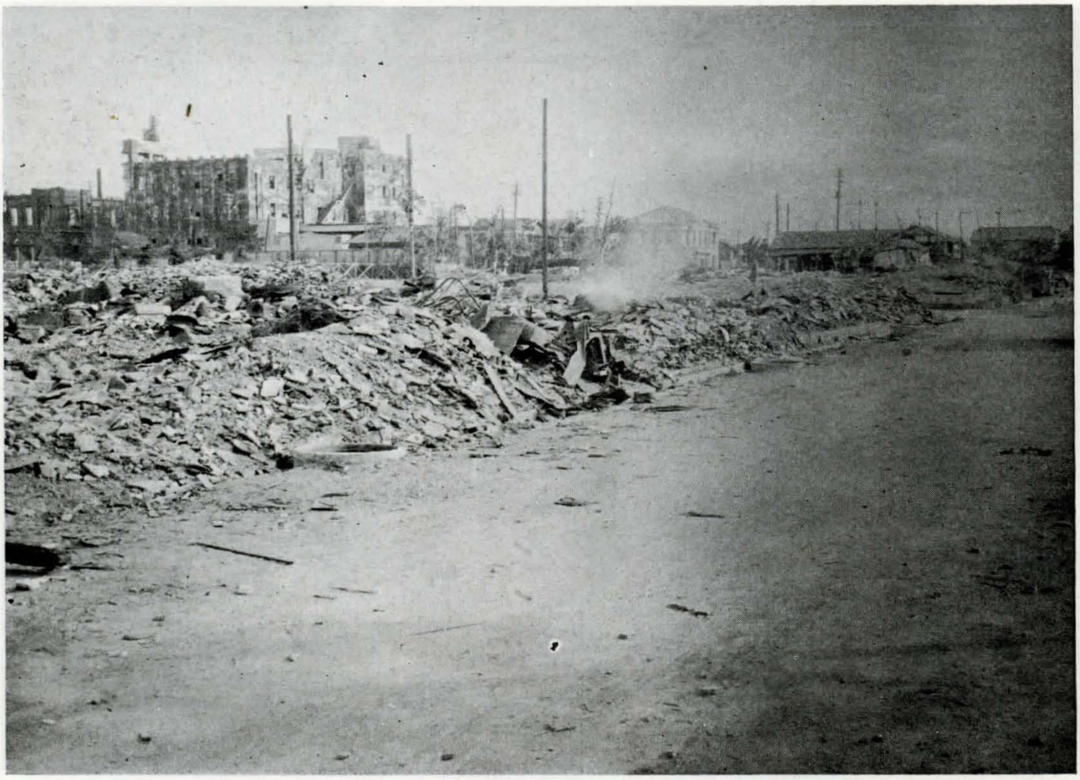


Photo 6.—Three typical static tanks almost flush with road. Prevalent in dwelling areas.

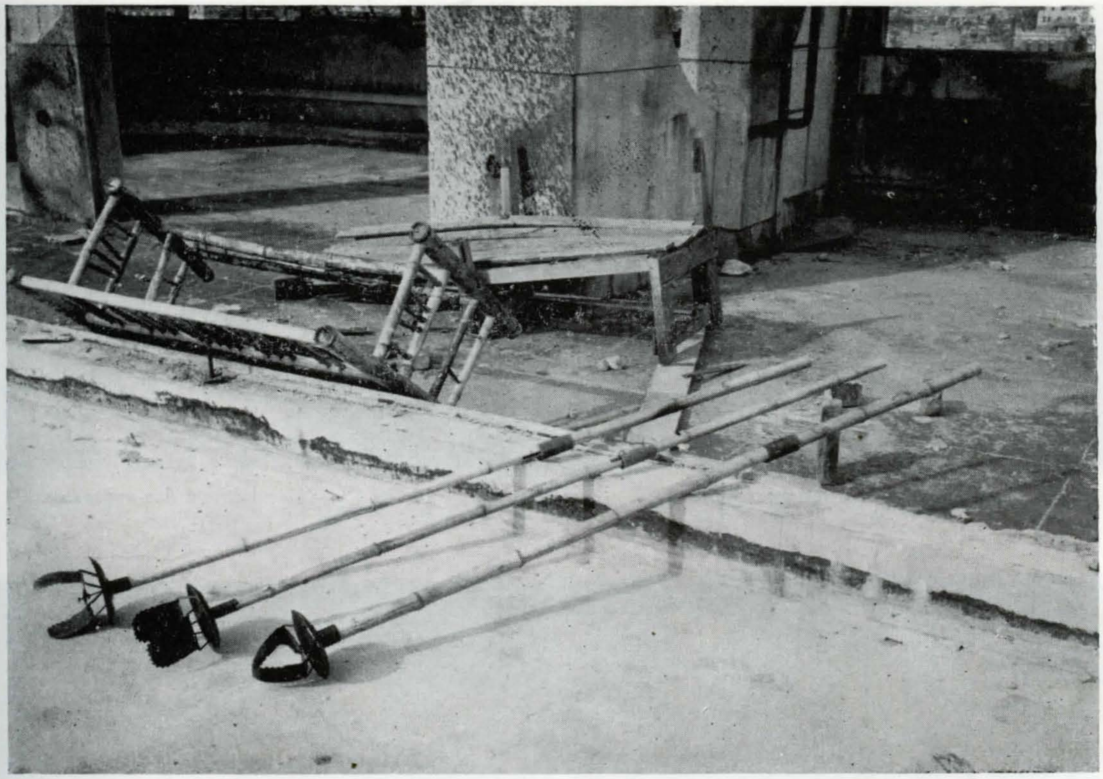


Photo 7.—Incendiary disposal implements. Noted on roof of department store.

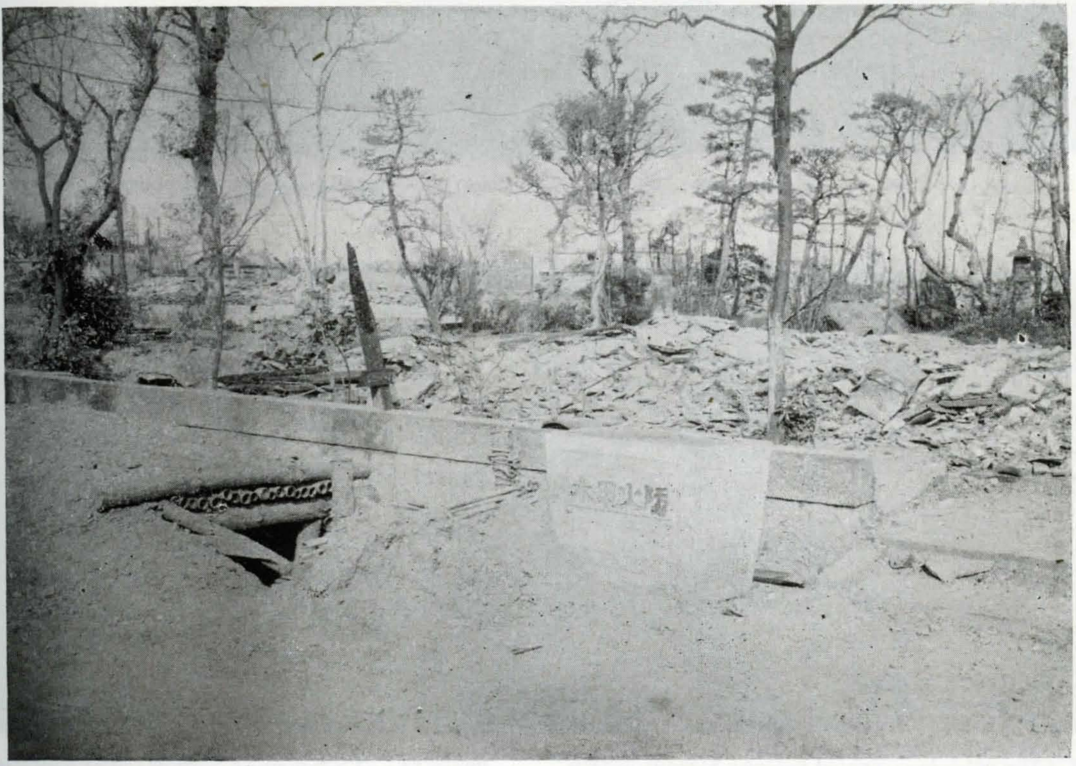


Photo 8.—Typical small static tank and shelter. Many of these noted in the city.

Photo 9.—Manually operated fire pumps.

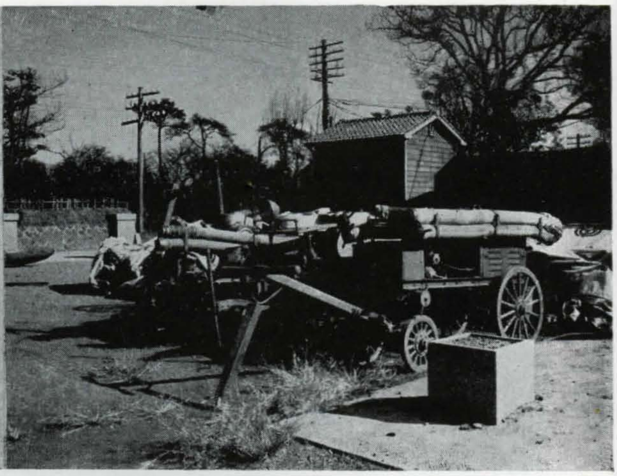


Photo 10. — Hand-drawn fire apparatus.

Photo 11.—Small manual fire pumps.

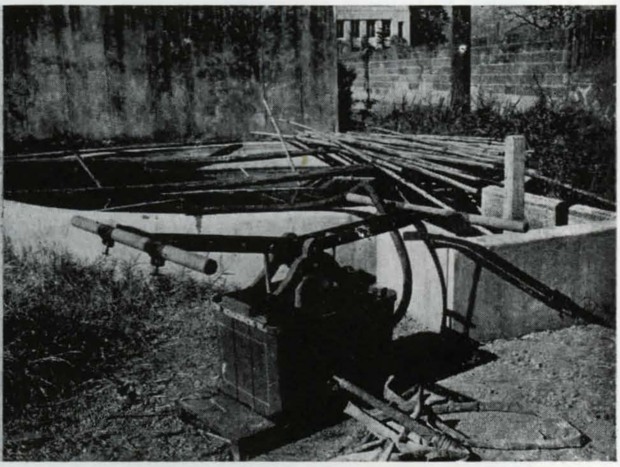


Photo 12. — Small hand-operated pump. Note hose and playpipe.

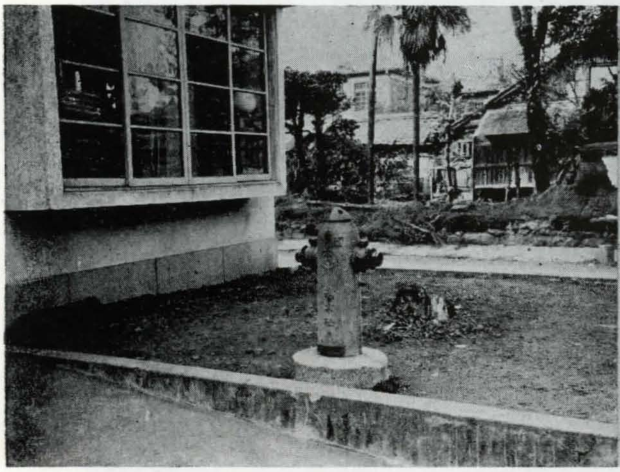


Photo 13.—The only above-ground two-way hydrant in Oita.

Photo 14. — Underground hydrant outlet with standpipe attached.

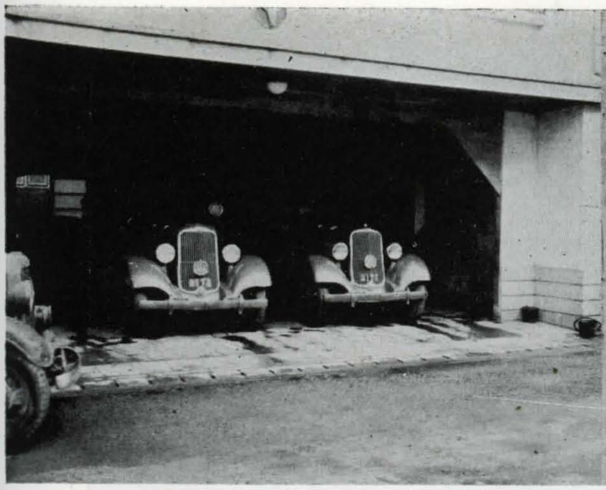


Photo 15.—Main fire station. Two combination trucks.

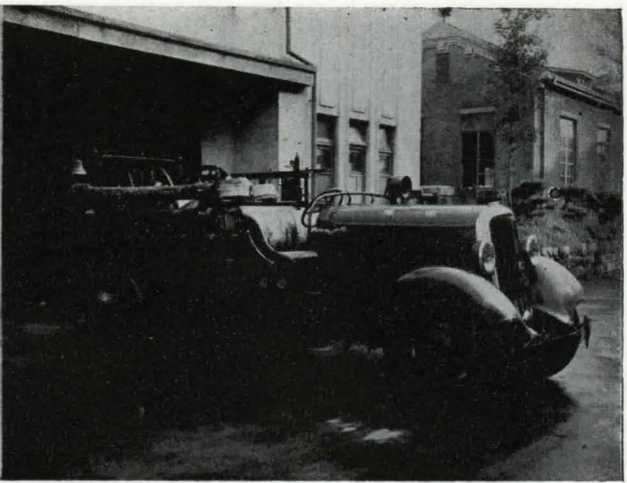


Photo 16.—Right side of combination fire truck.

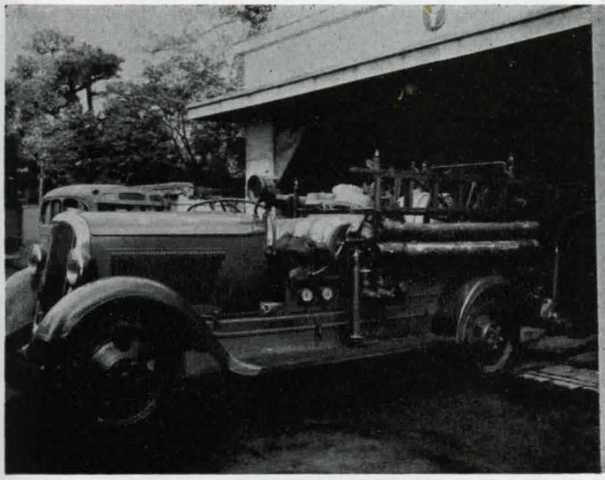


Photo 17.—Left side of combination fire truck.

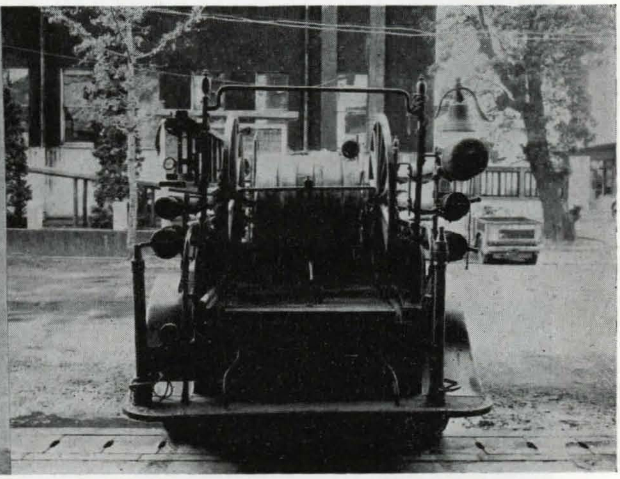


Photo 18.—Rear view of fire truck.

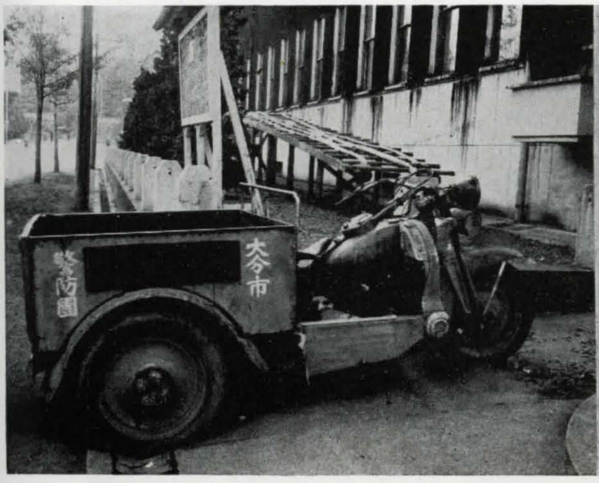


Photo 19. — Two-cylinder tricycle. Used to carry hose, nozzles, extinguishers.

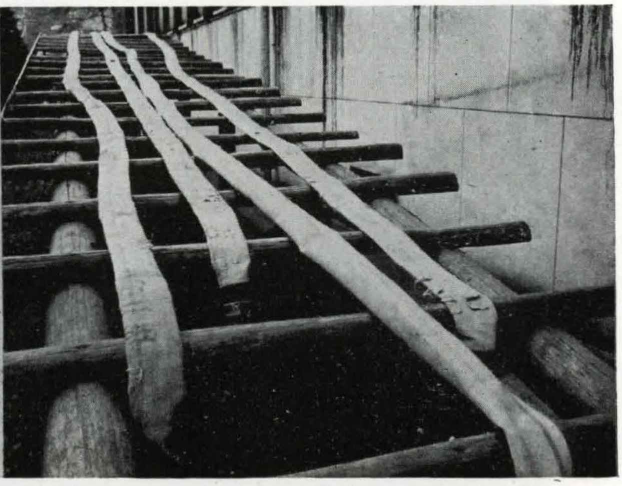


Photo 20.—Drying rack for hose. Note innumerable patches.

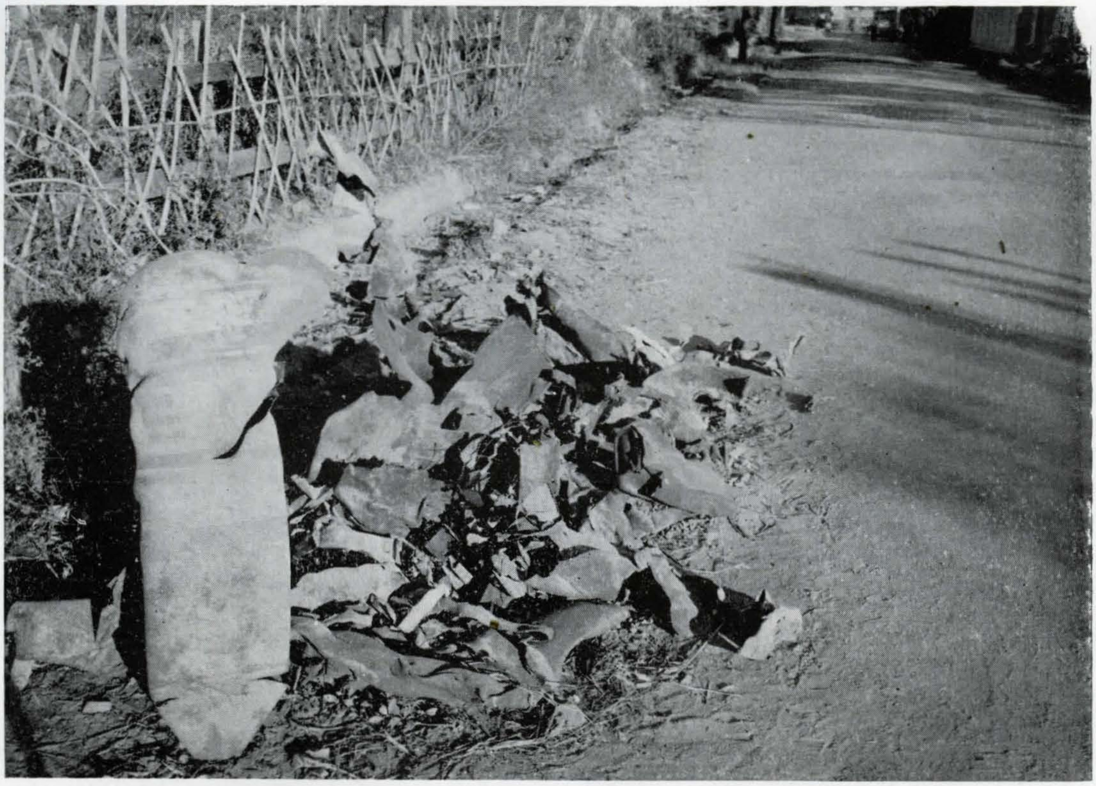


Photo 21.—M47 fragment scraps and one complete casing.

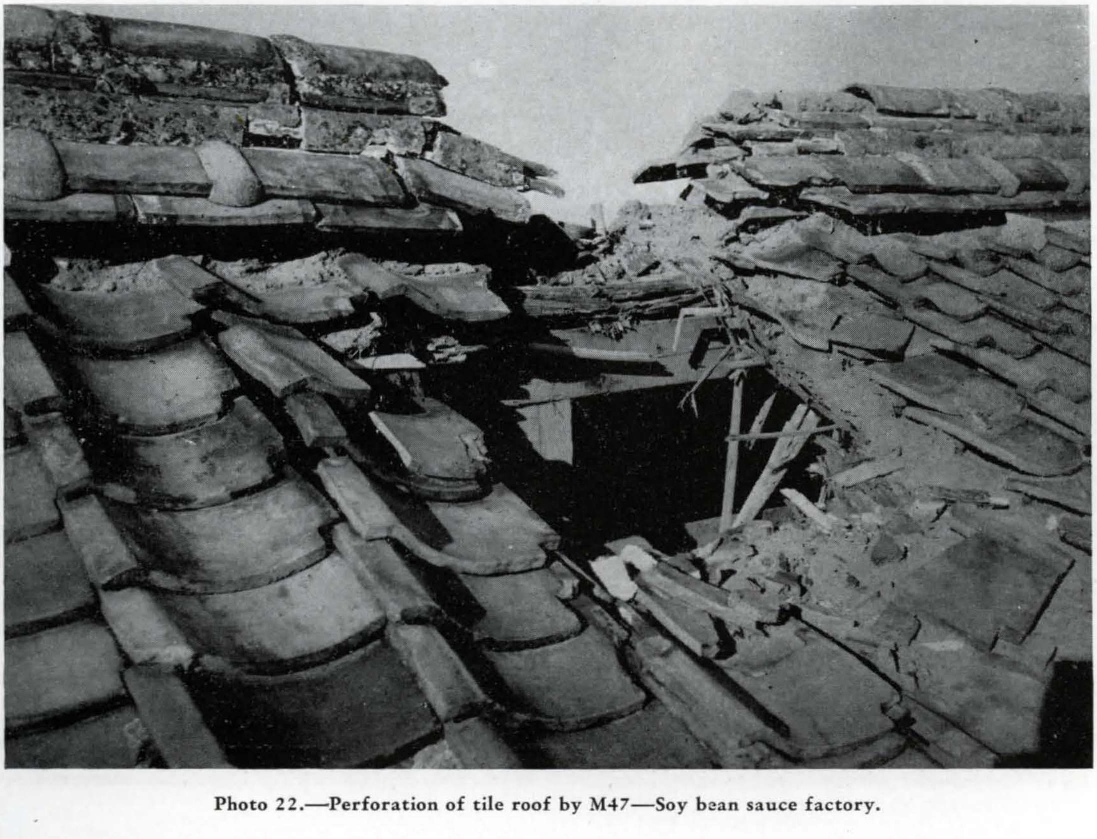


Photo 22.—Perforation of tile roof by M47—Soy bean sauce factory.

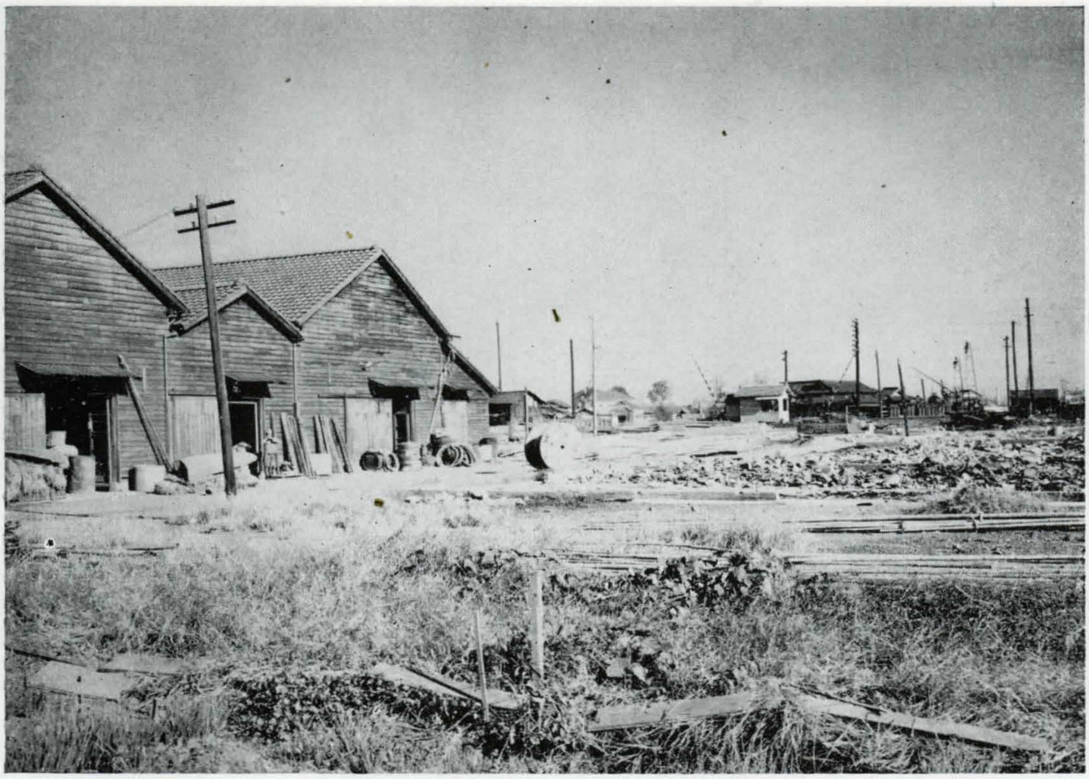


Photo 23. — Burned-out area right. Buildings on left separated by 20-foot streets, unburned.

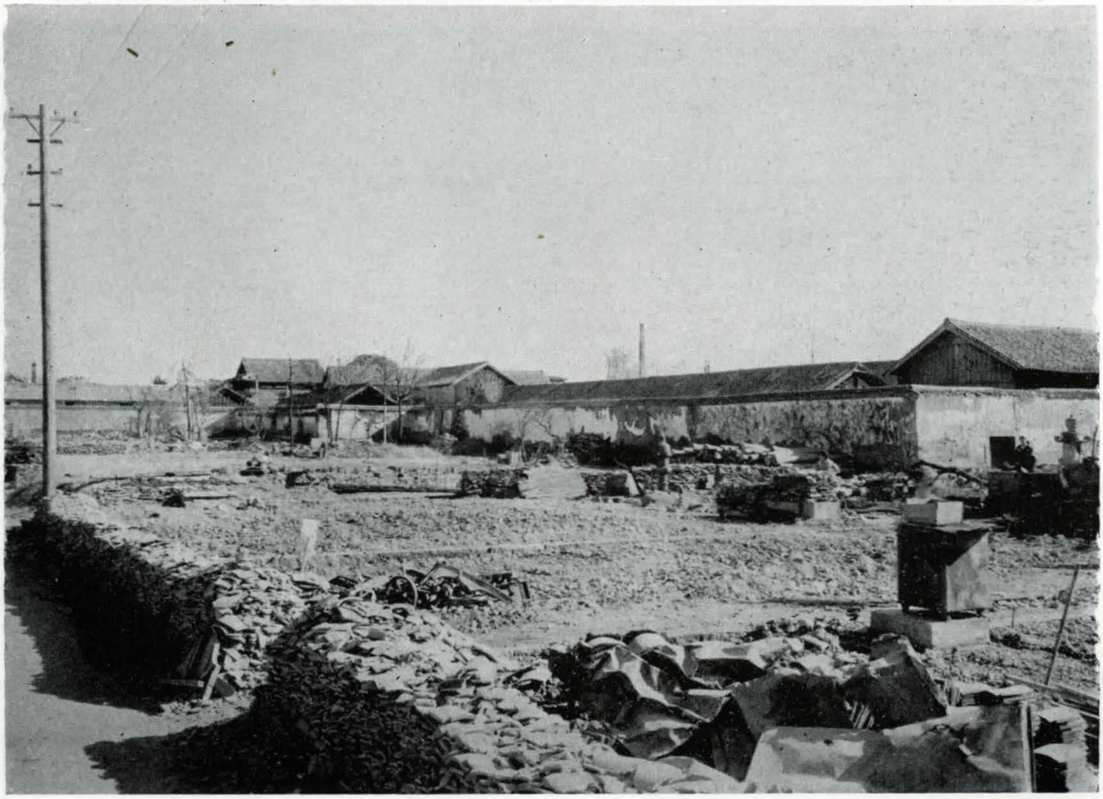


Photo 24.—Concrete and mud wall around prison, which stopped fire spread.

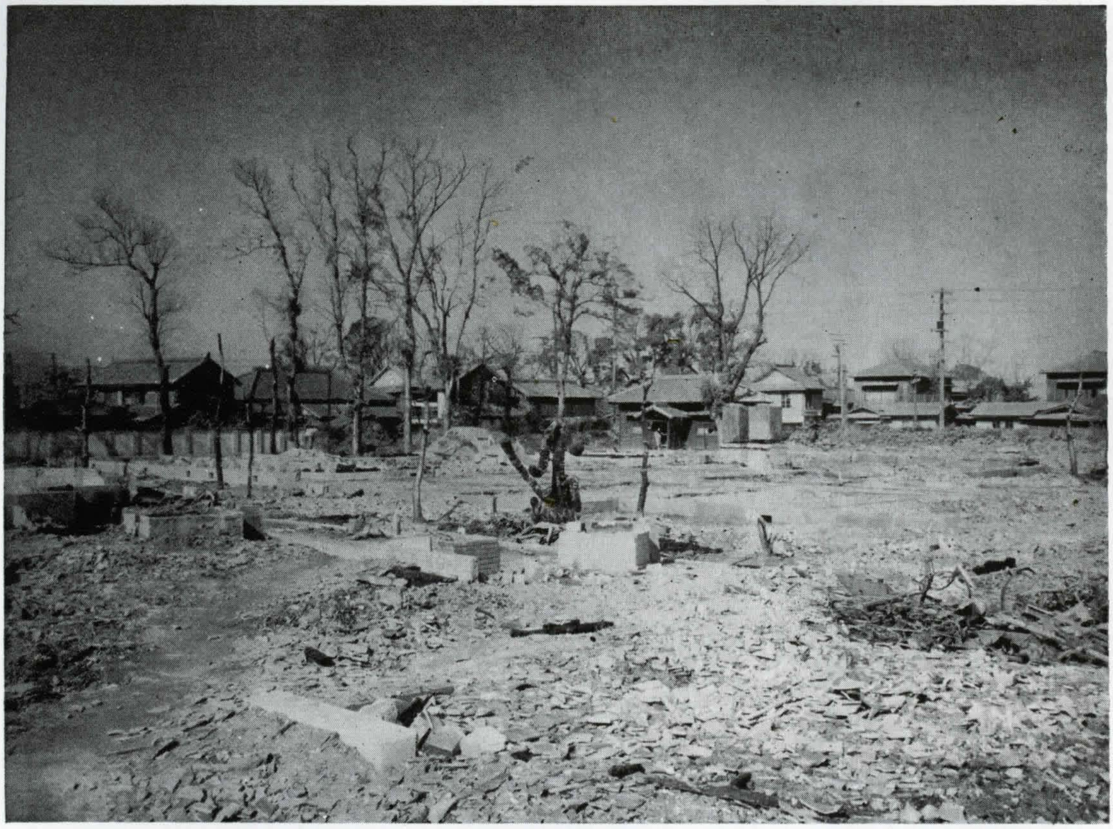


Photo 25. — General view north of courthouse, all buildings except dozo record vault destroyed.

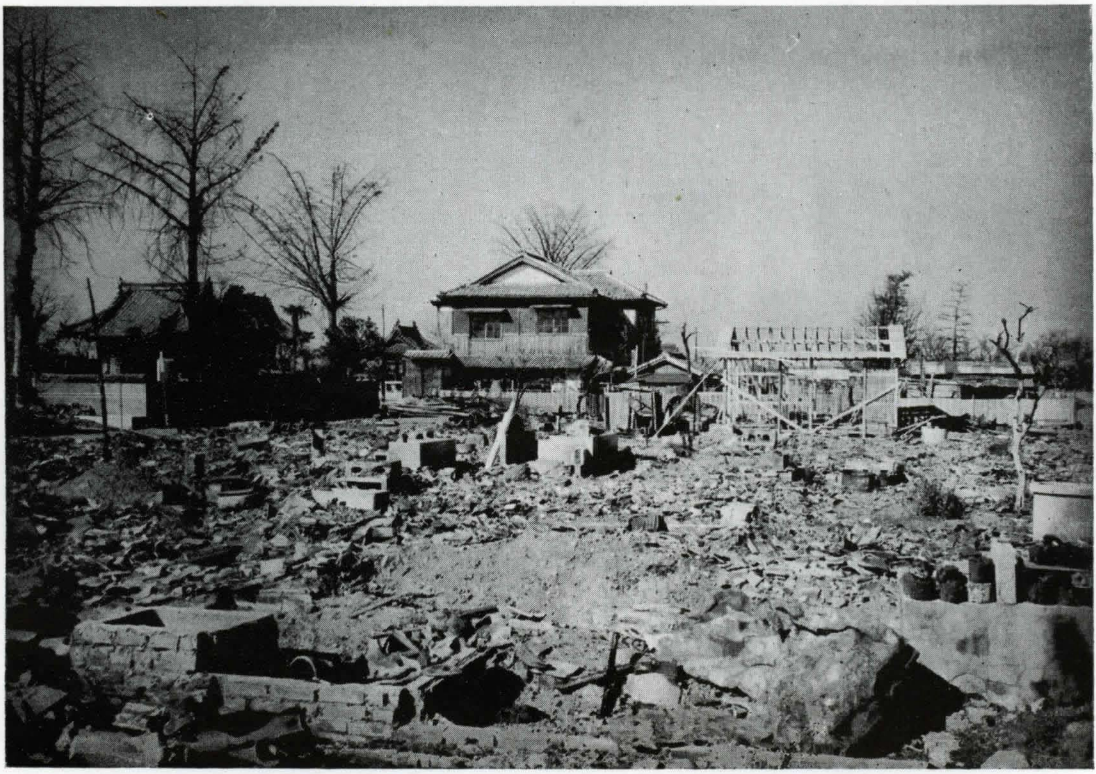


Photo 26.—Timber radio shop and dwelling saved by bucket brigade.

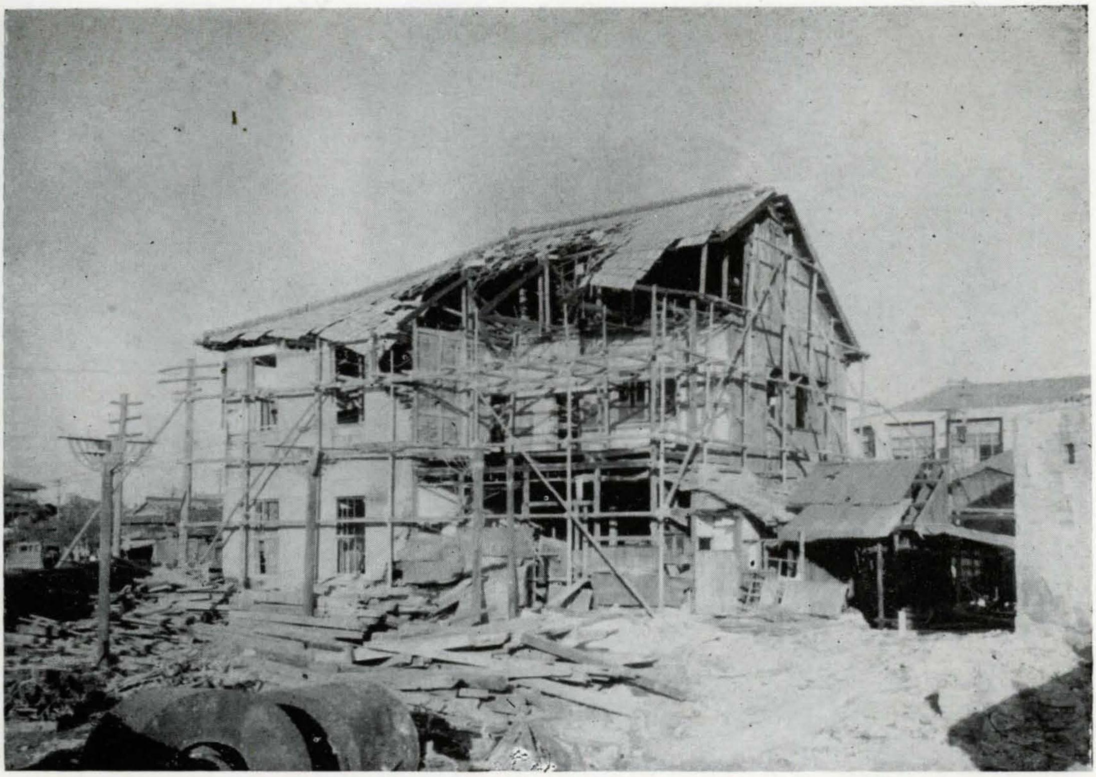


Photo 27.—Printing shop damaged by fire. M47 exploded in yard. Repairable and under reconstruction.

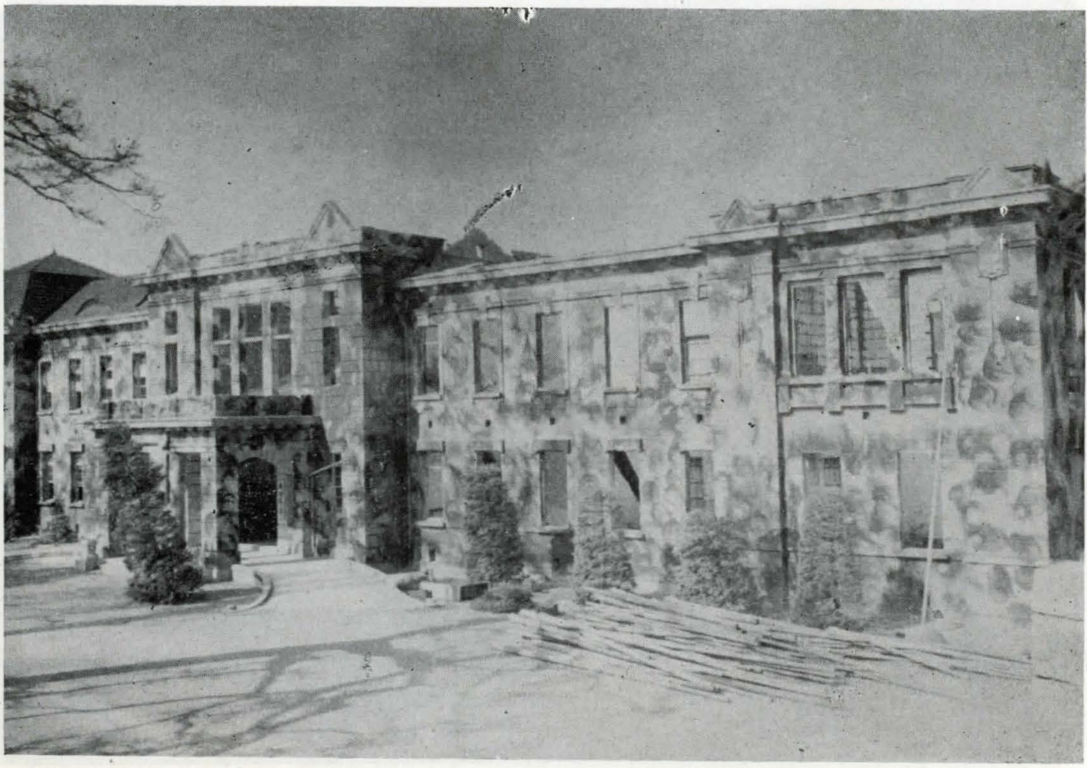


Photo 28. — Northwest side prefecture building burned.

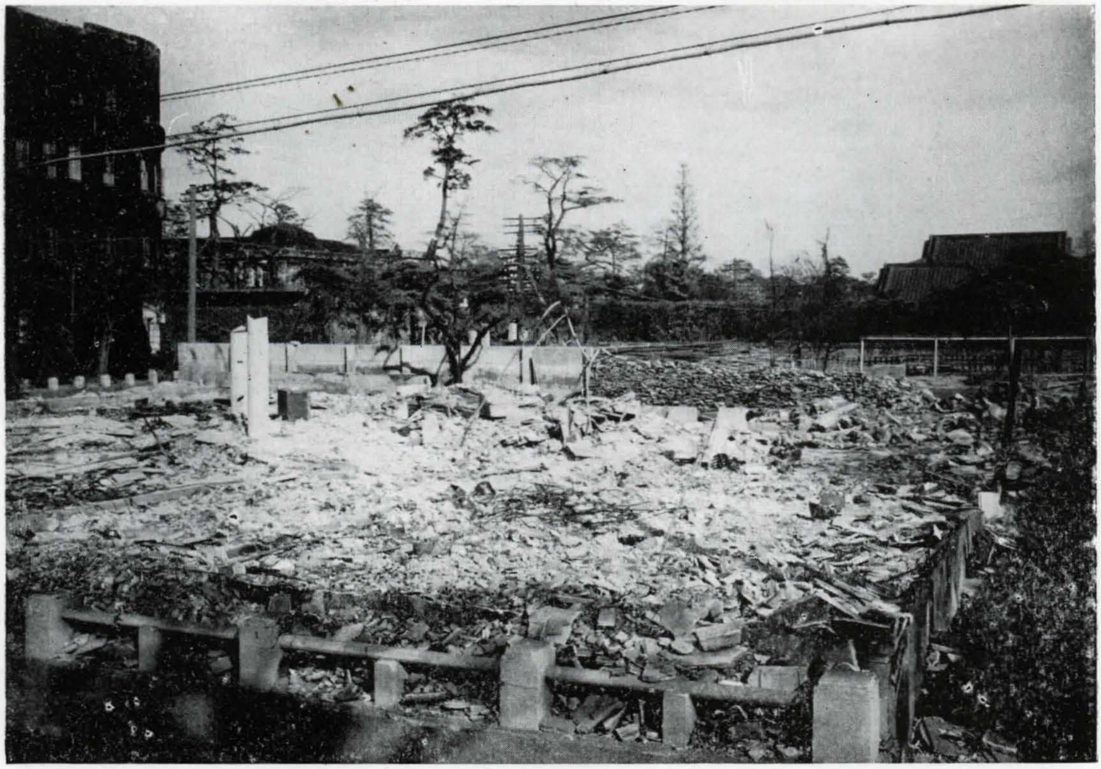


Photo 29.—Combustible store completely destroyed, located in center of city.

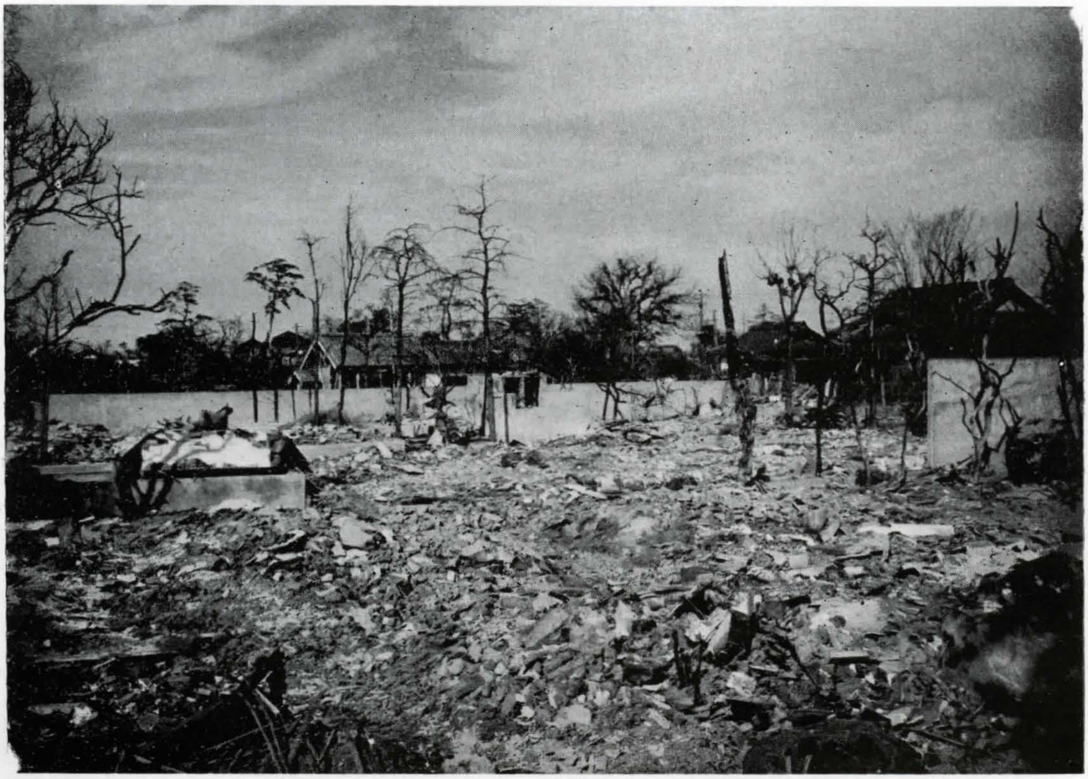


Photo 30. — All buildings destroyed both sides of five-foot-high masonry wall.

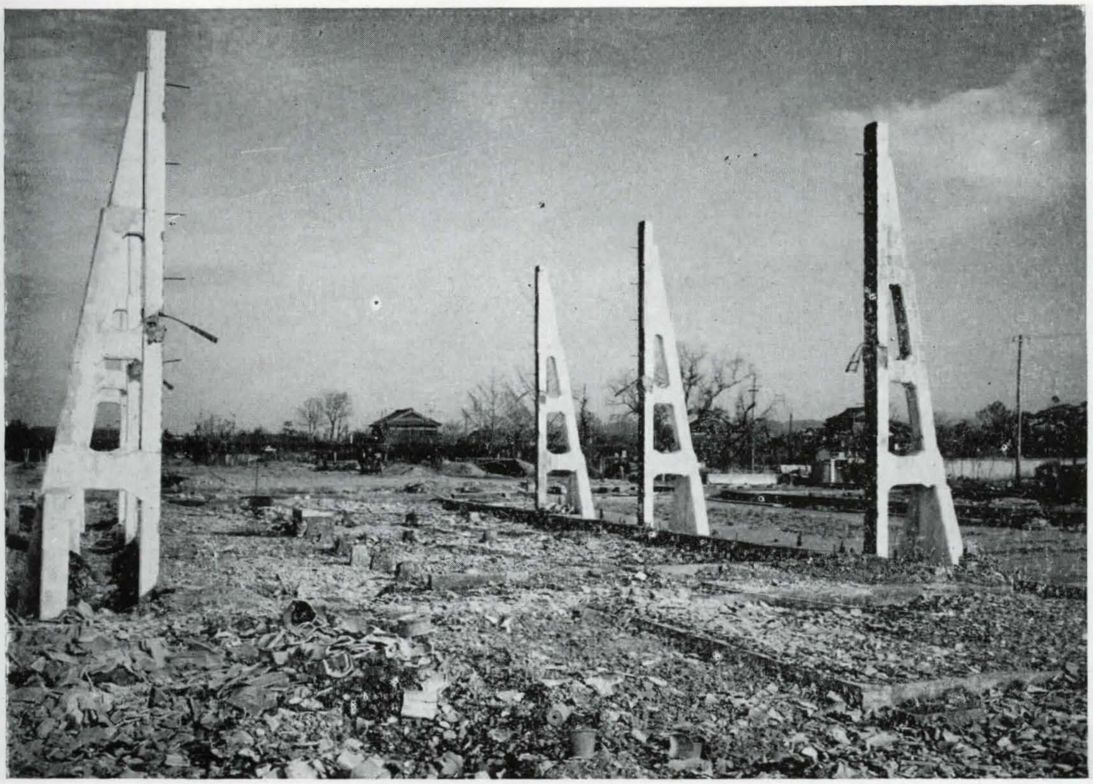


Photo 31.—School building burned. Buttresses standing.

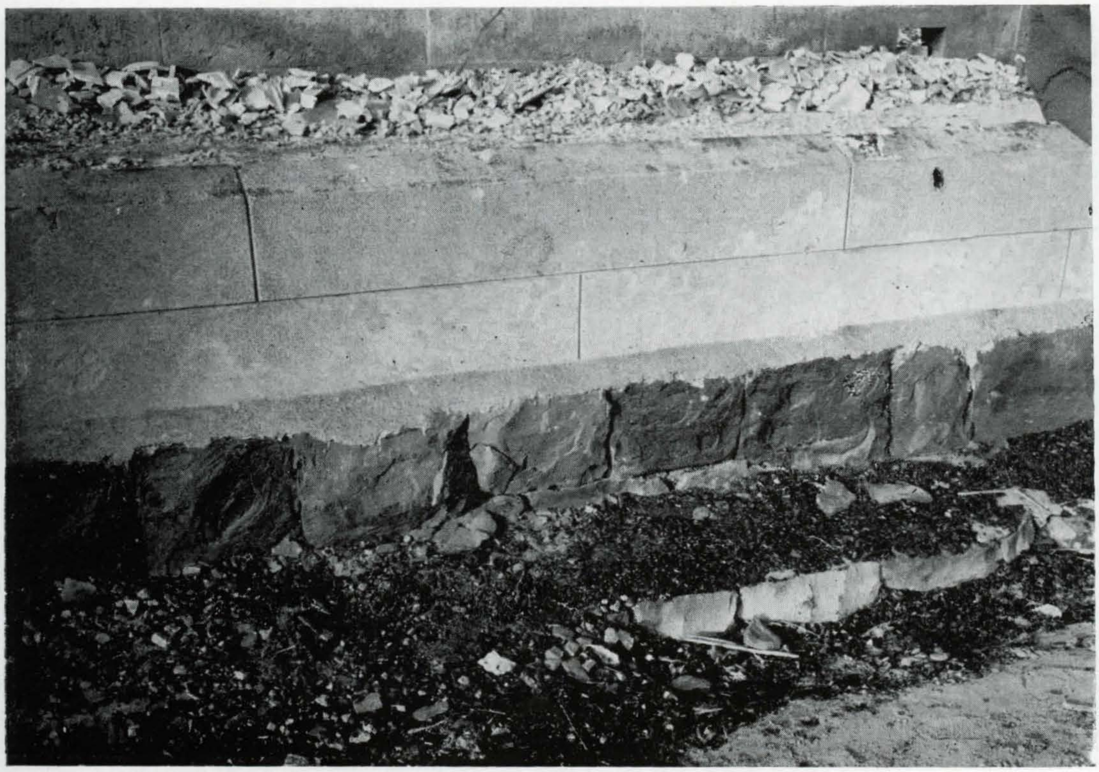


Photo 32.—Spalling of stone footing due to intense heat.

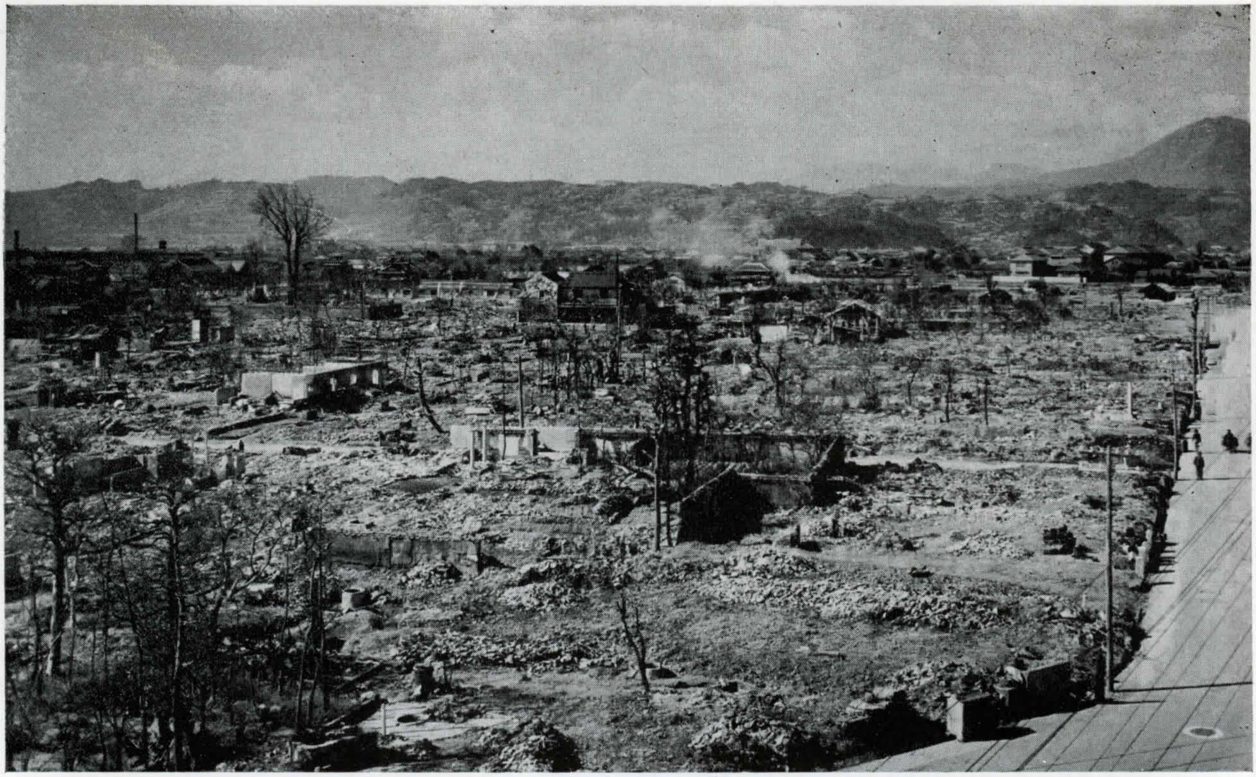


Photo 33.—General destruction. Looking west from Building 10.

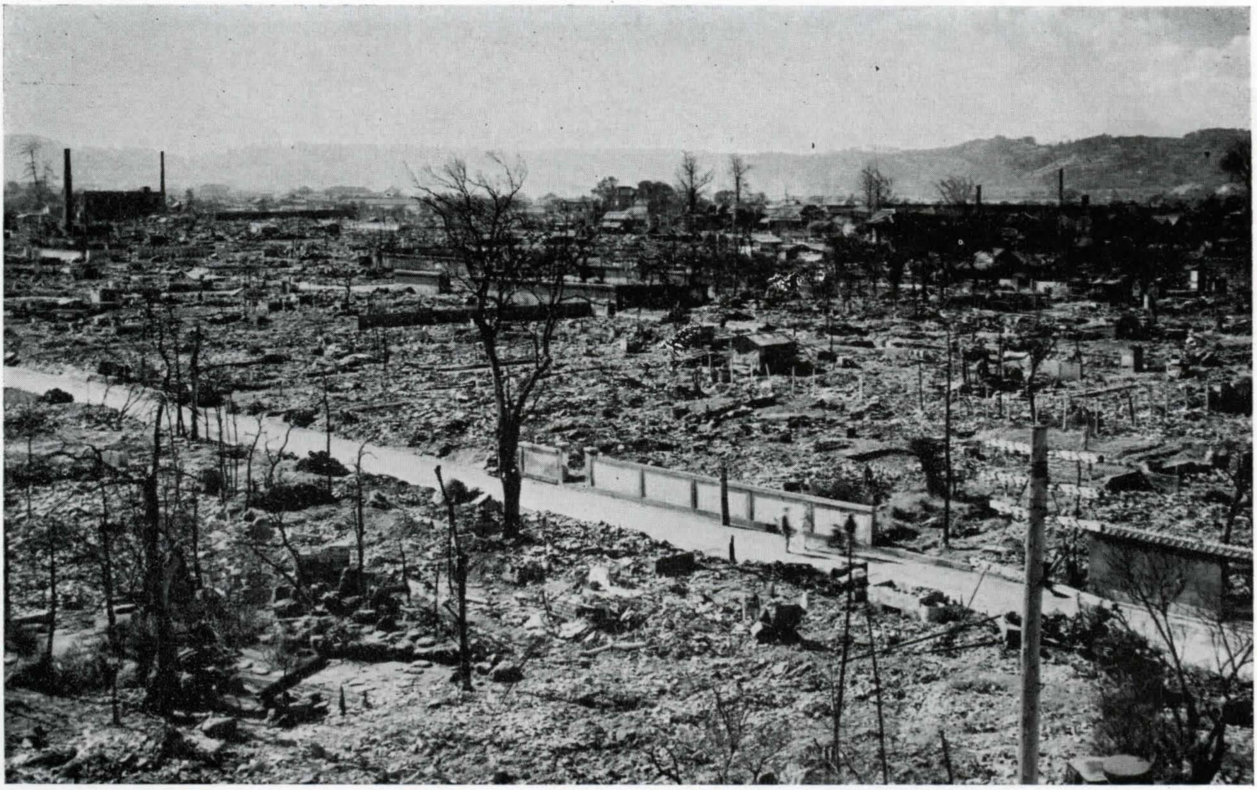


Photo 34.—General destruction. Looking southeast from Building 10.

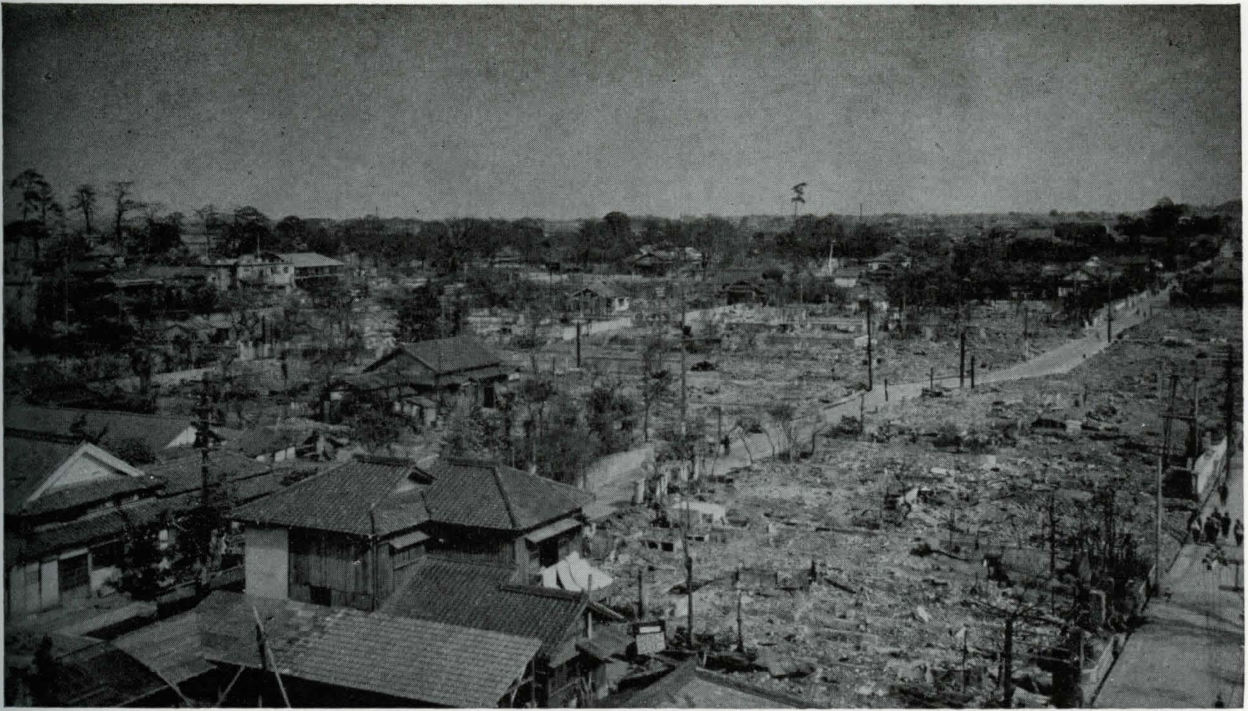


Photo 35.—Destroyed area east from Building 14.

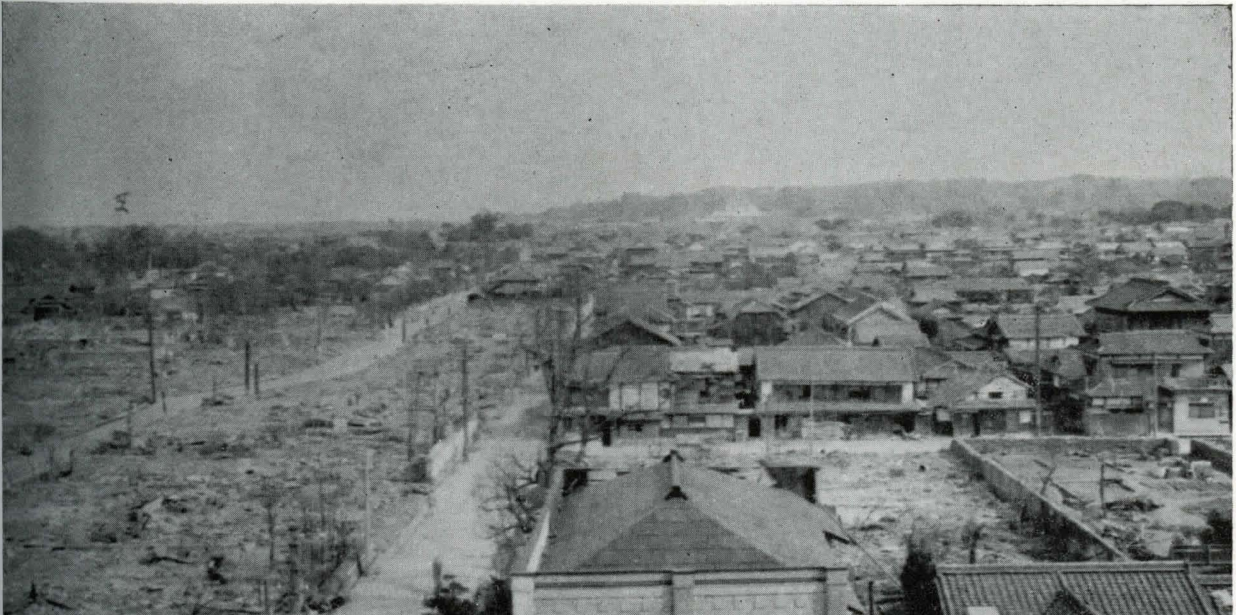


Photo 36.—Destroyed area southeast from Building 14.

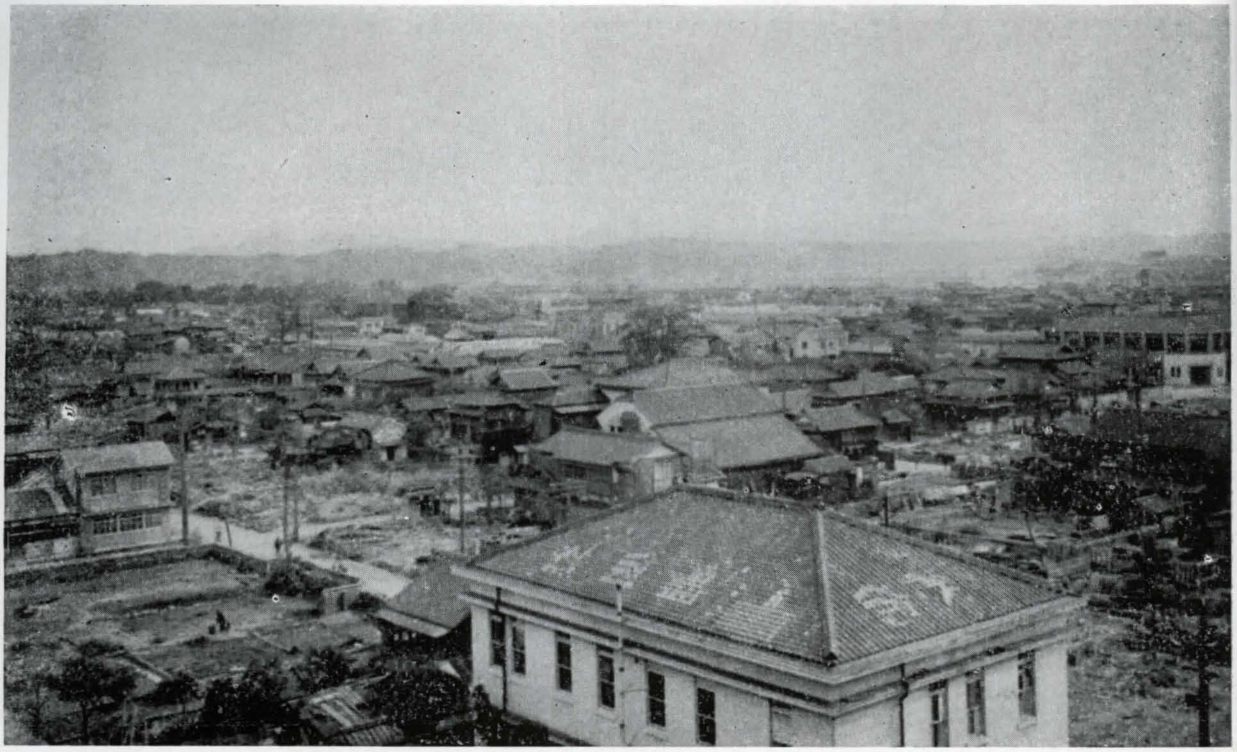


Photo 37. — Destruction south from Building 14.

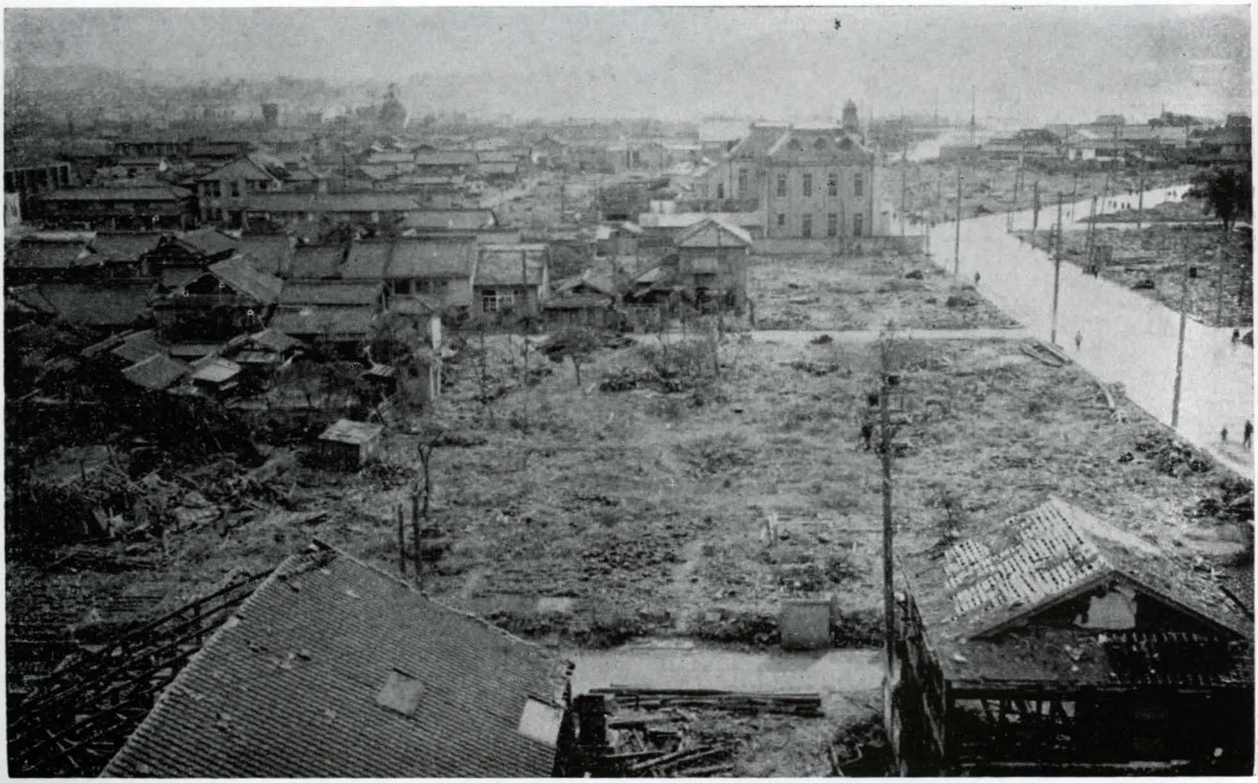


Photo 38. — Destruction southwest from Building 14.

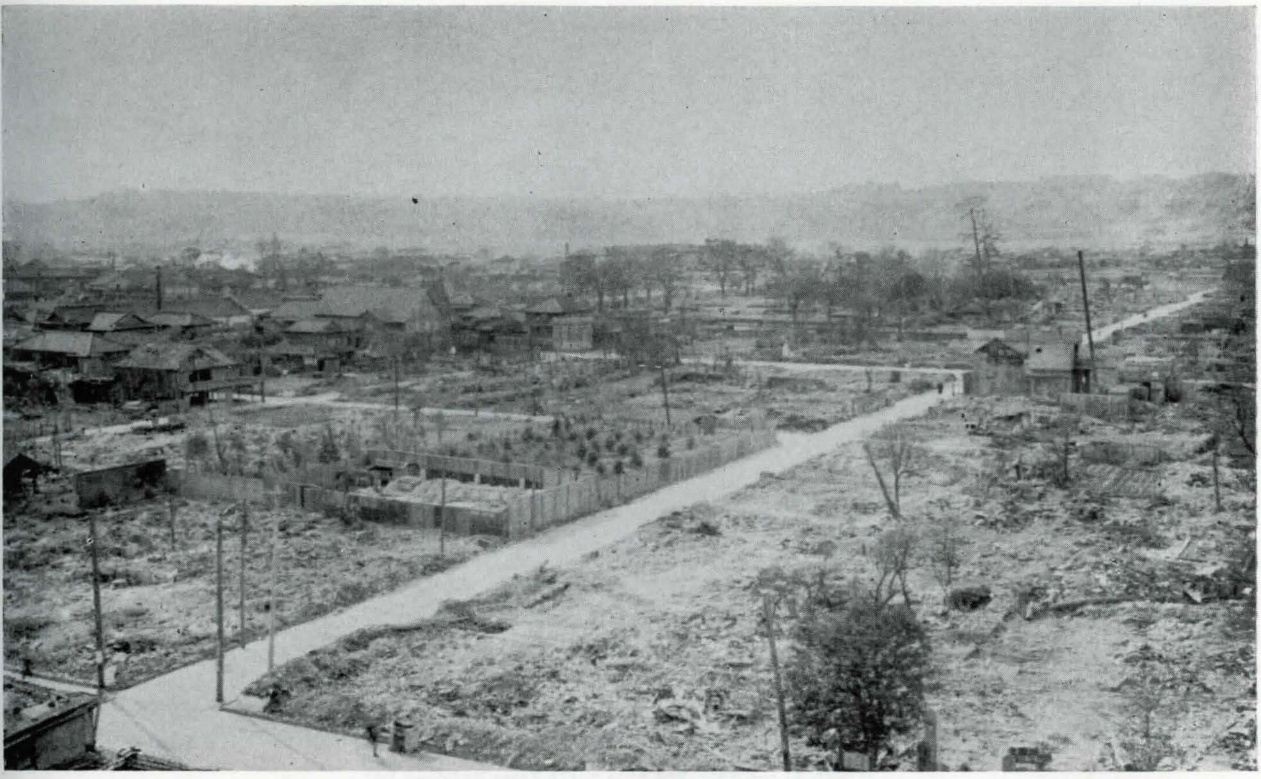


Photo 39.—Destroyed area west from Building 14.

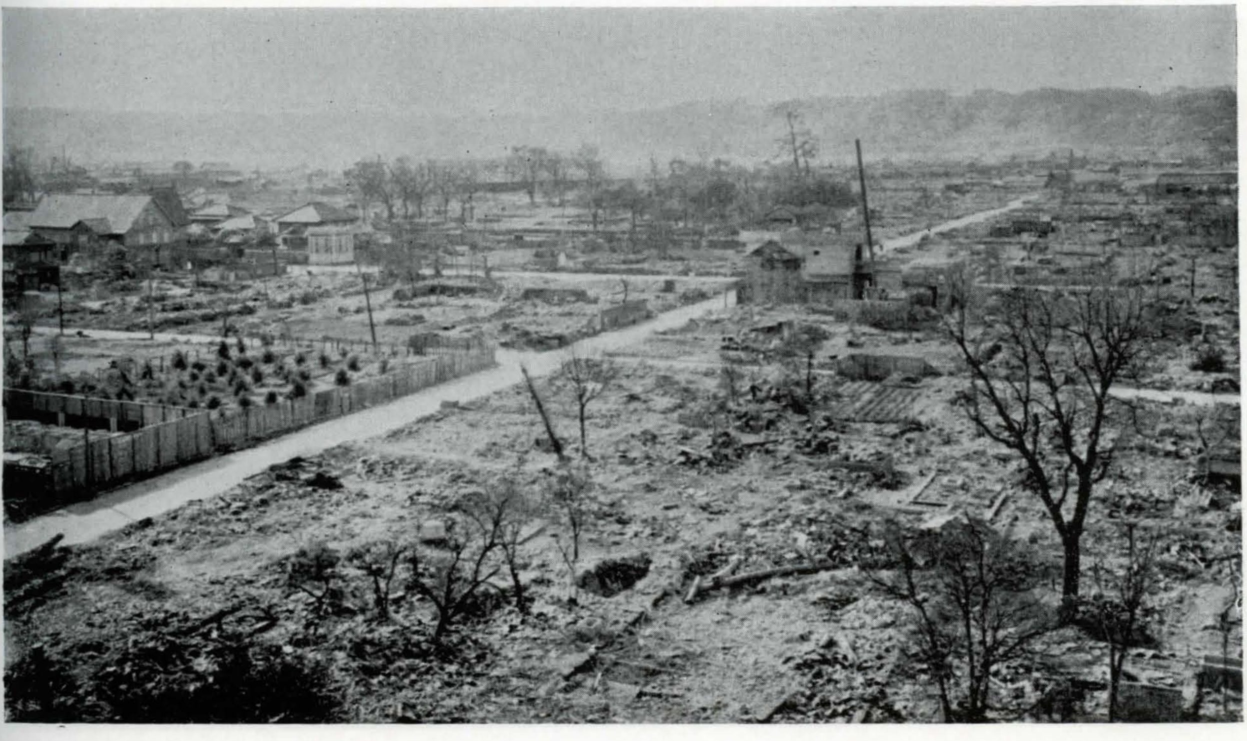


Photo 40.—Destroyed area northwest from Building 14.

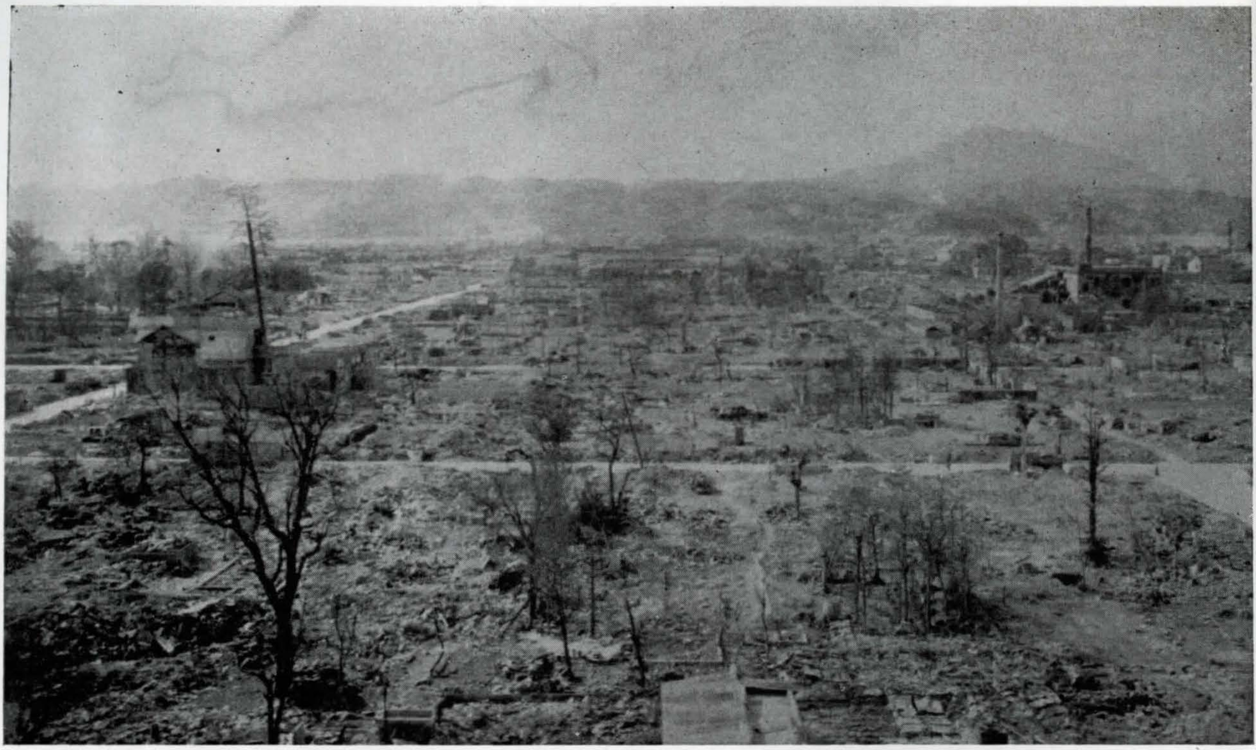


Photo 41.—Destroyed area north from Building 14.

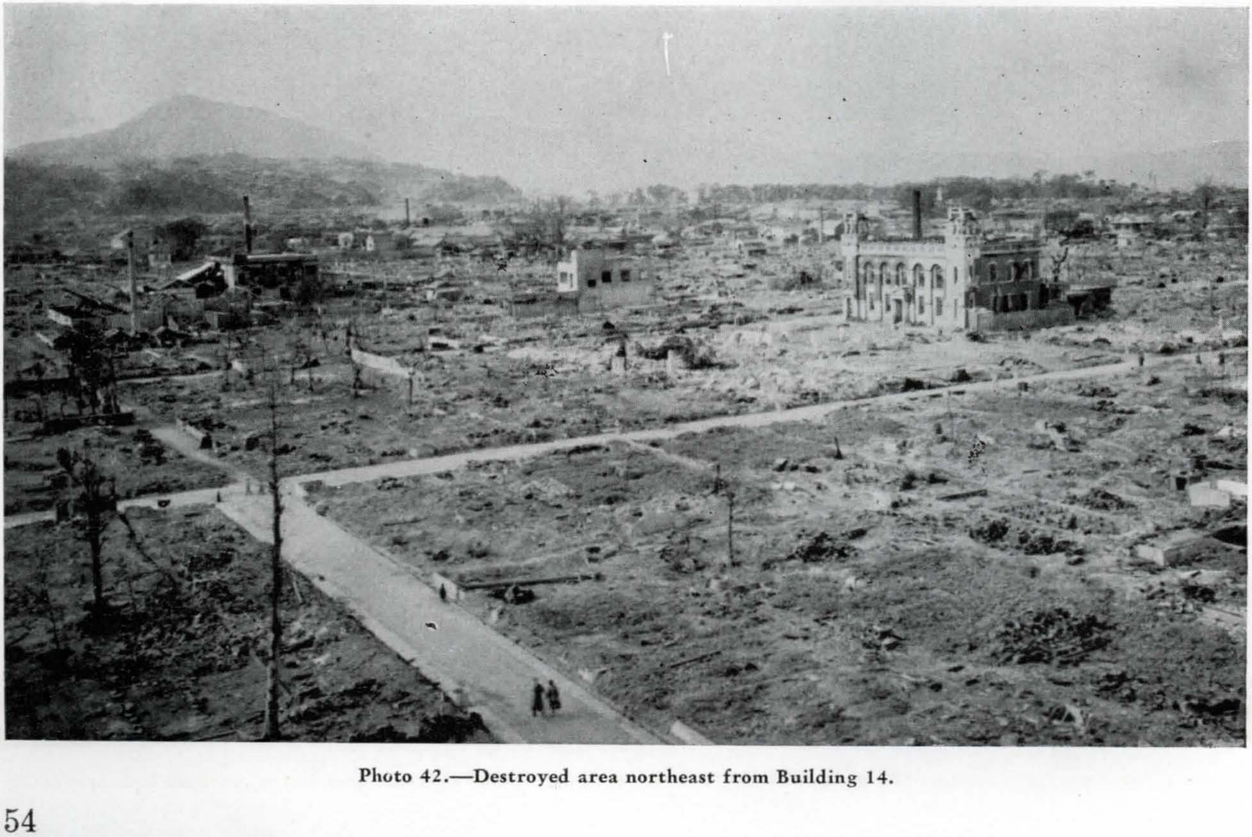


Photo 42.—Destroyed area northeast from Building 14.

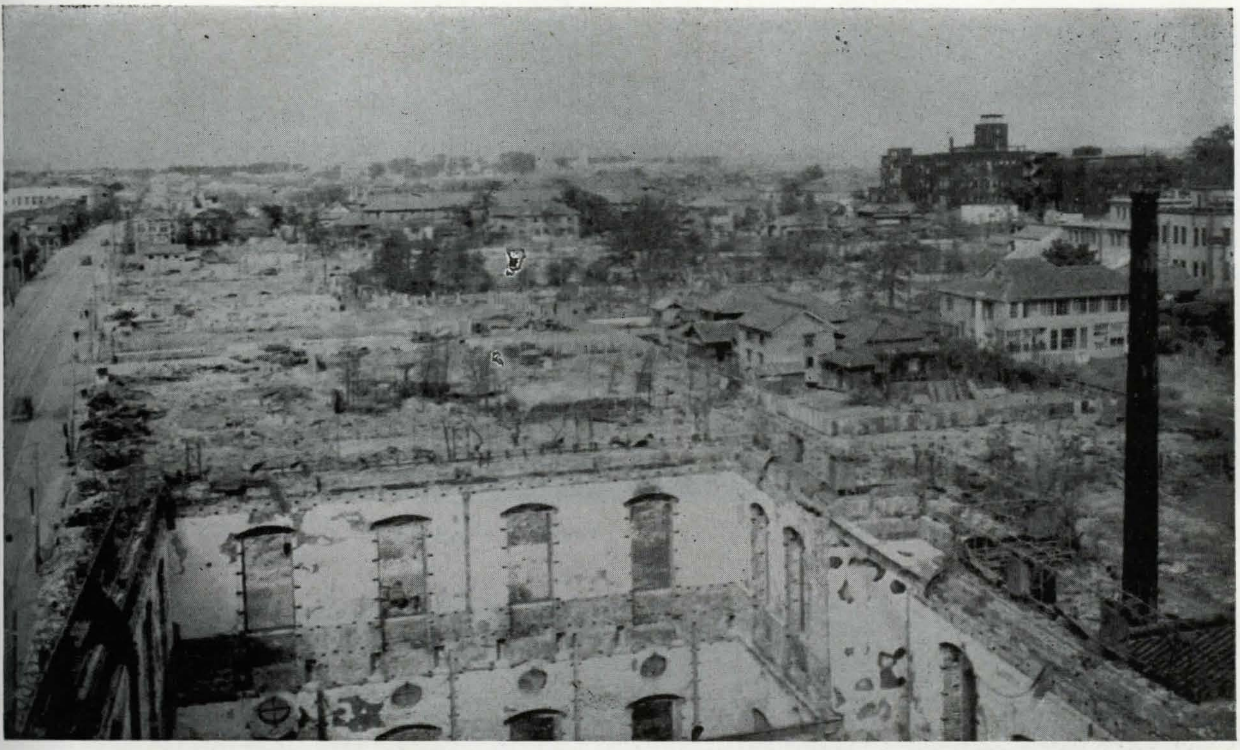


Photo 43.—General view of burned business district.

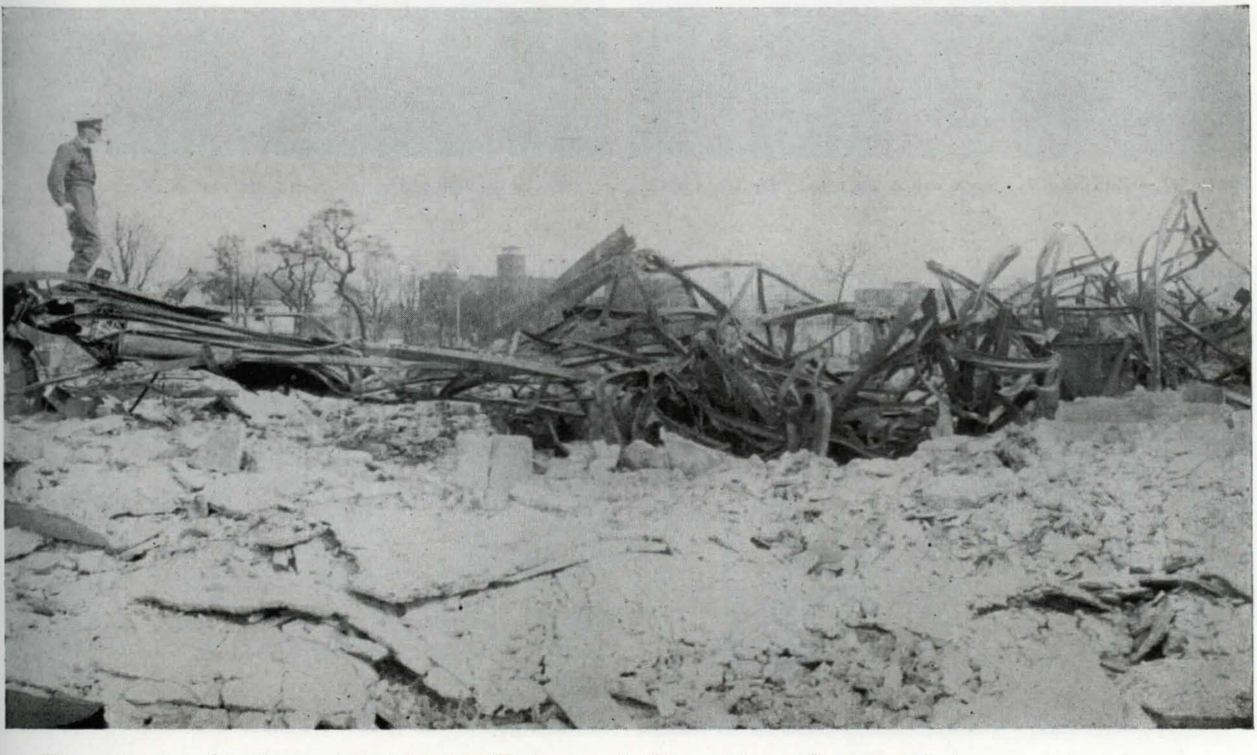


Photo 44.—Complete destruction of combustible business building. Note collapsed steel elevator shaft and tower.

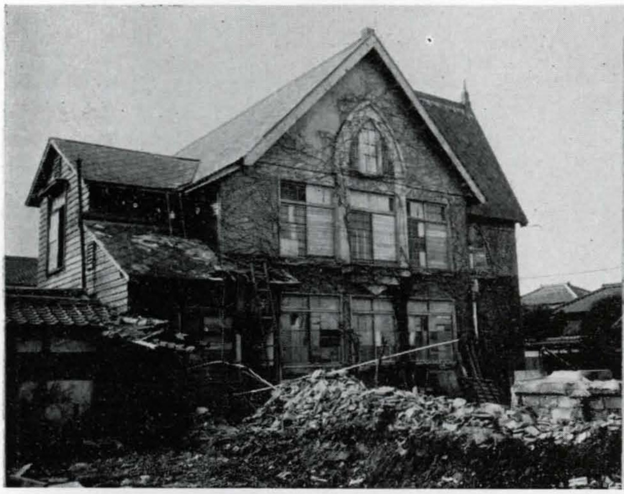


Photo 45.—Building 1. Presbyterian Church.

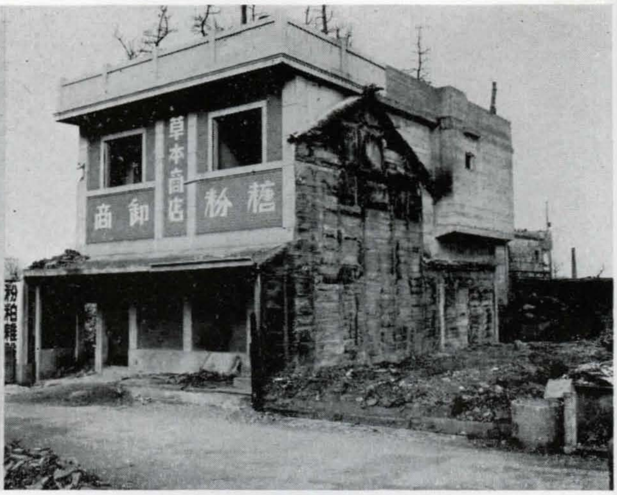


Photo 46.—Building 2. Confectionary manufacturing and dwelling.

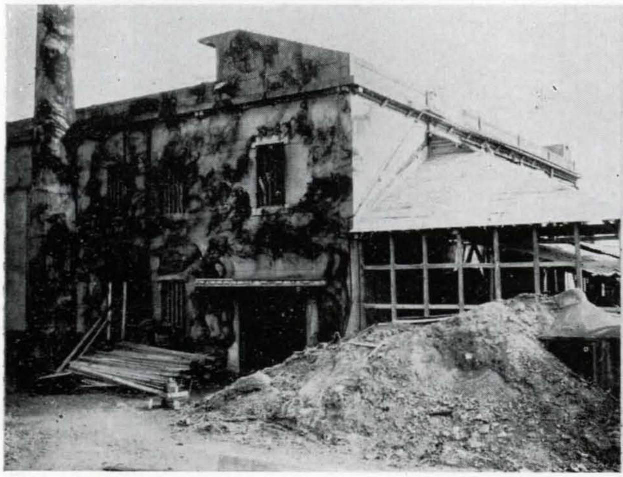


Photo 47.—Building 3. Soya sauce factory. Contents fire.

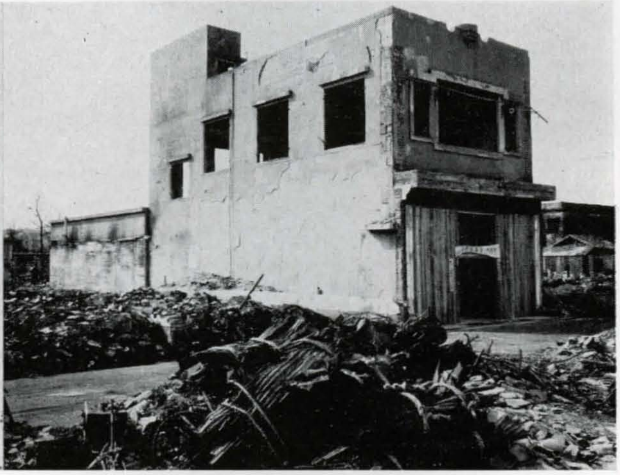


Photo 48.—Building 4. Mercantile shop. Contents fire.

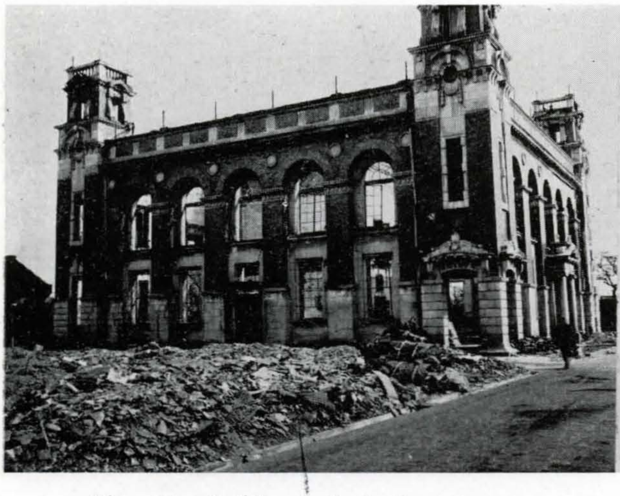


Photo 49.—Building 5. Bank. Burned out.

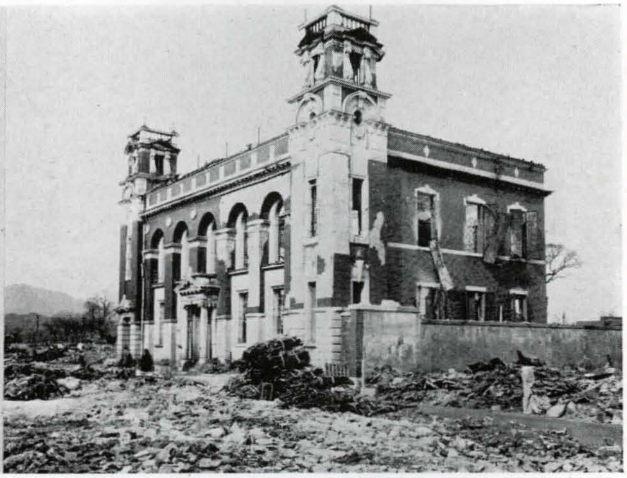


Photo 50.—Building 5. Bank. Northwest view.

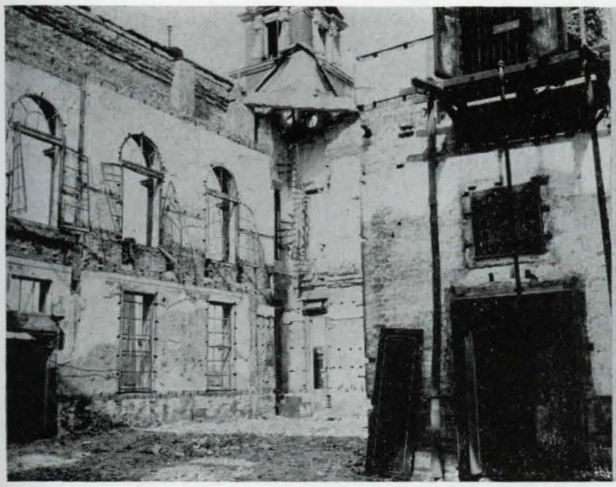


Photo 51.—Building 5. Interior destroyed. Vault at right.

Photo 52.—Building 6. Nippon Bank. Undamaged.

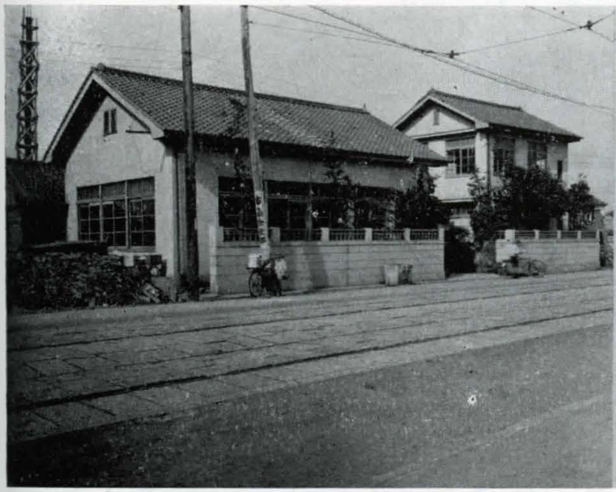


Photo 53.—Building 7. Post Office. Undamaged.

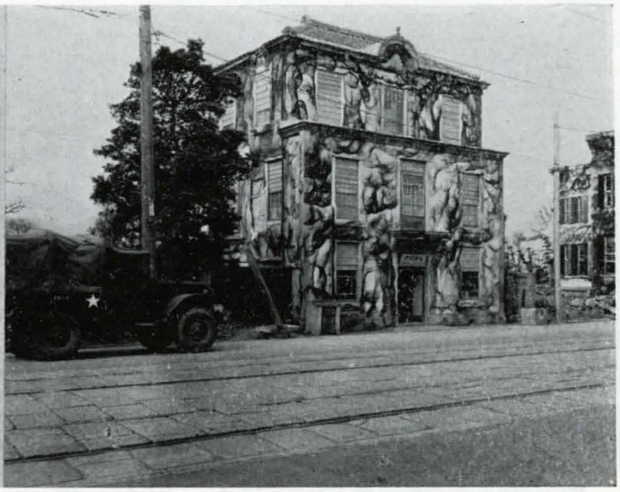


Photo 54.—Building 8. Dispensary. Undamaged.

Photo 55.—Building 9. Bank. Minor damage.

Photo 56.—Building 10. Bank. M47 did not perforate roof.

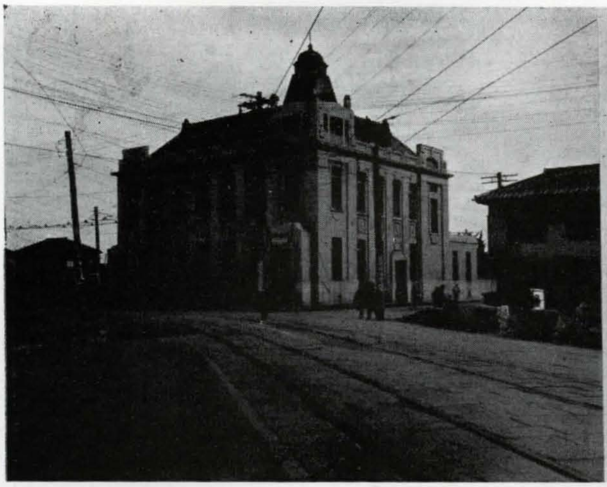


Photo 57.—Building 11. Probable police station. Undamaged.

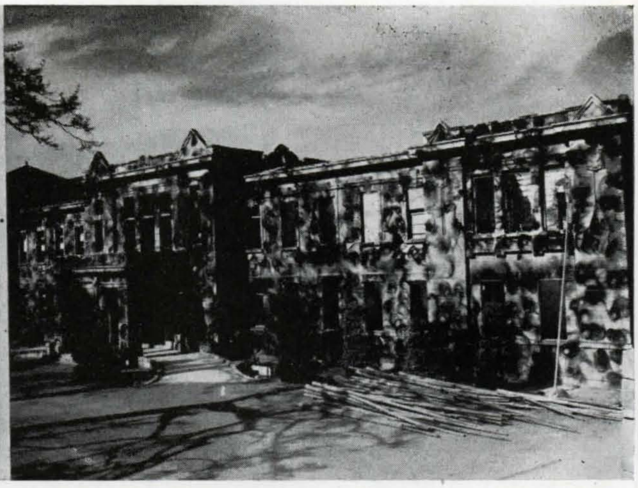


Photo 58.—Building 12. Prefecture. Partly burned.

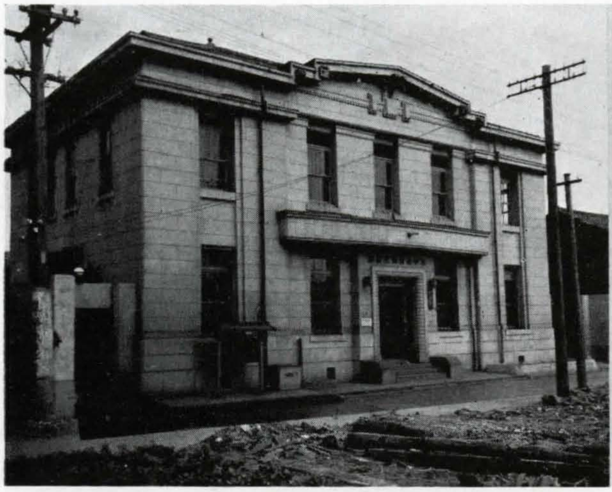


Photo 59.—Building 13. Bank. Undamaged from IB action.

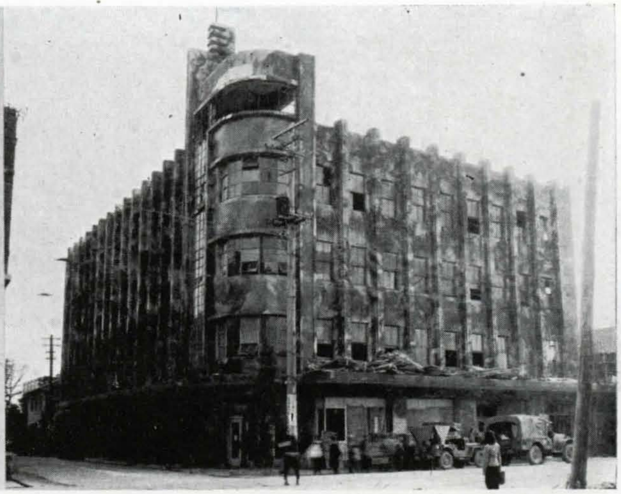


Photo 60.—Building 14. Department store. Partly damaged by fire.

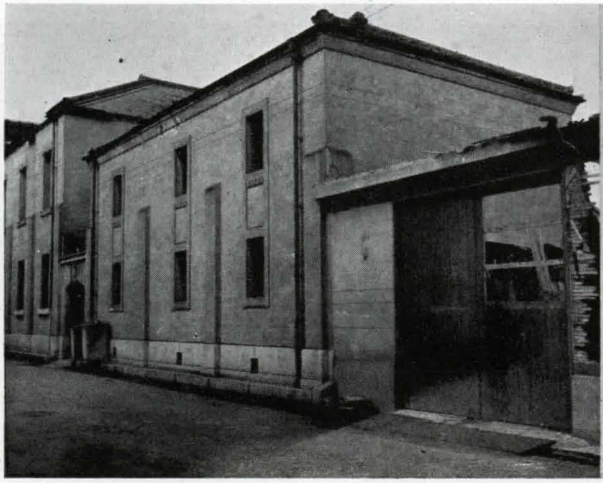


Photo 61.—Building 15. Bank. Minor fire damage.

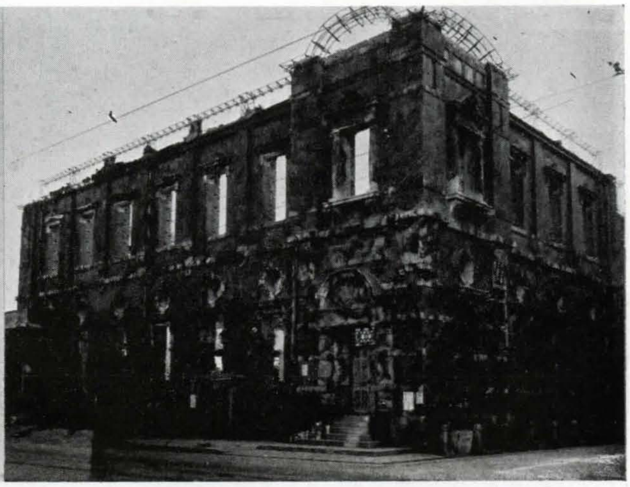


Photo 62.—Building 16. Bank. Interior burned.

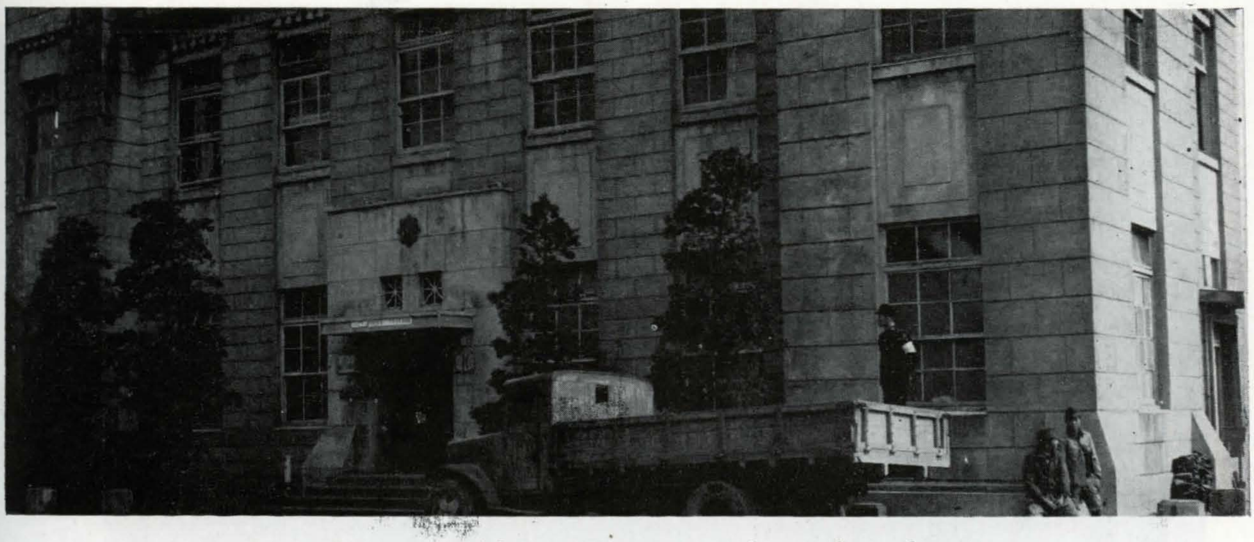


Photo 63.—Building 19. Oita police station. Undamaged.

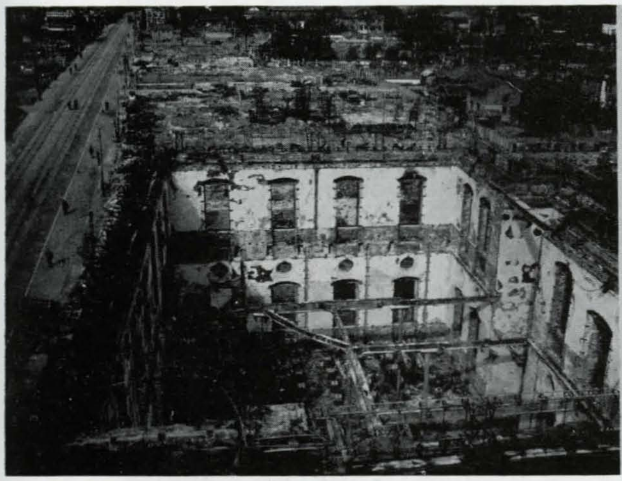


Photo 64.—Building 16. Complete destruction of interior.

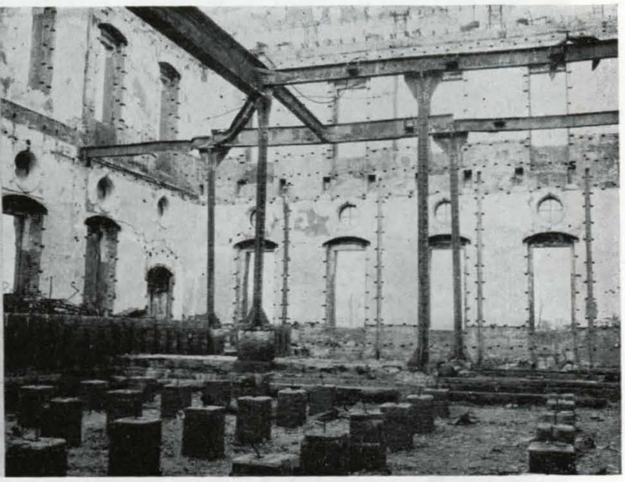


Photo 65.—Building 16. Interior of main banking room.

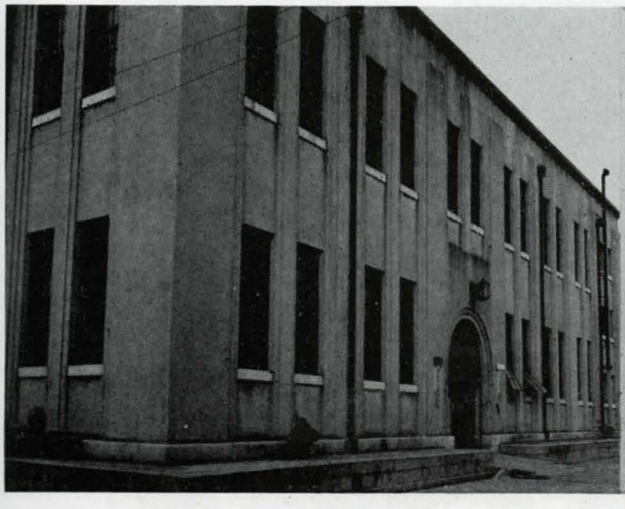


Photo 66.—Building 17. Telephone Exchange. Undamaged.

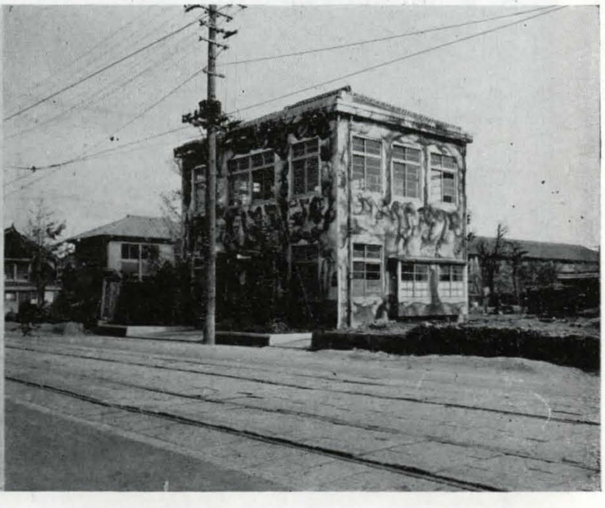


Photo 67.—Building 18. Insurance Company. Undamaged.

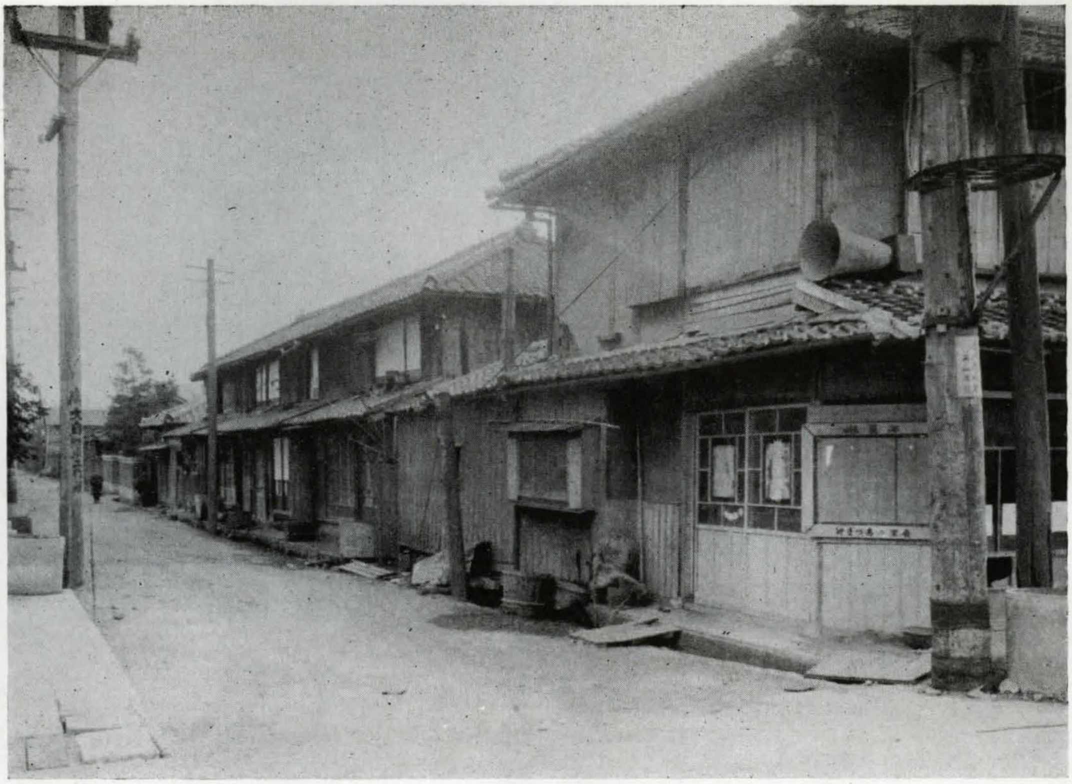


Photo 68.—Typical street. One- and two-story dwellings.

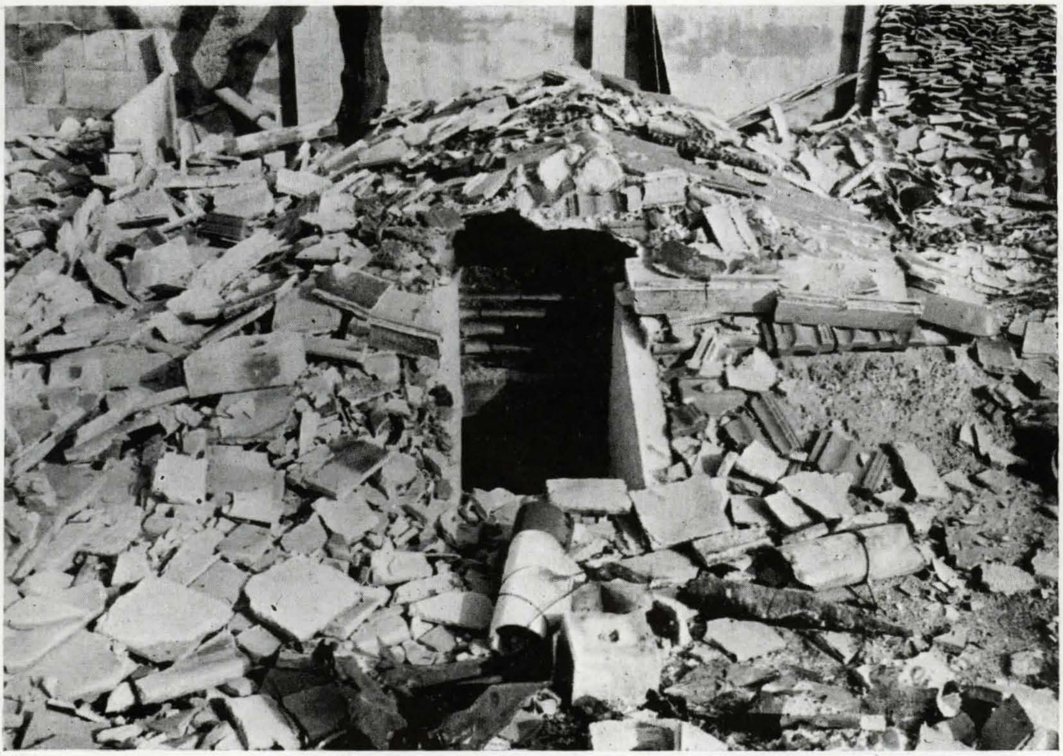


Photo 69.—Public air-raid shelter.

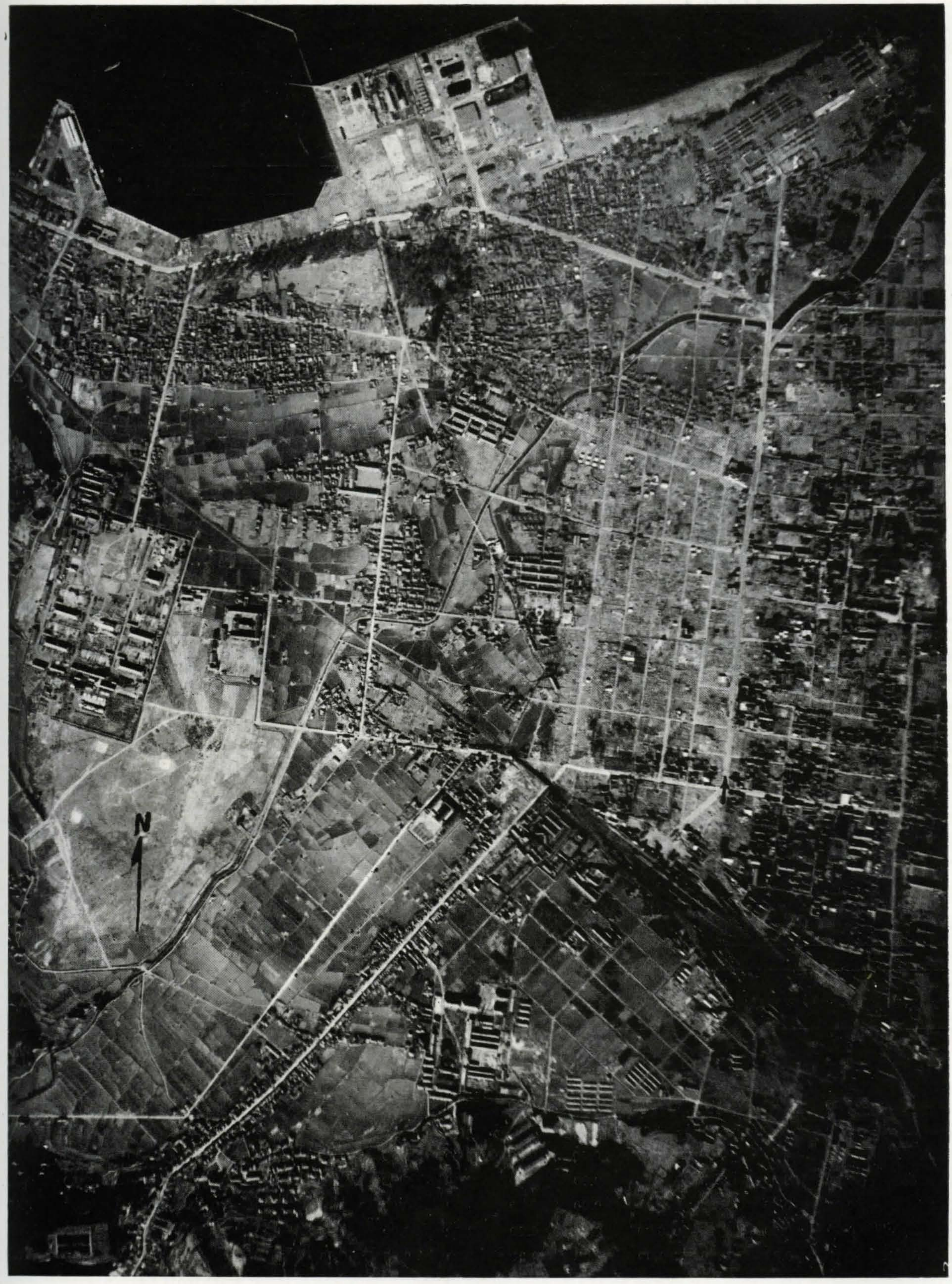


Photo 70.—Post-raid cover. Note completeness of destruction in concentrated area west of main business street which is indicated by arrow.

TABLE 1

AVERAGE TEMPERATURES AND HUMIDITY

Date	*Average temperature (degrees C)*	*Average humidity (percent)*
July 1945:		
10	23.23	85.0
11	27.33	78.3
12	22.33	96.0
13	22.70	88.7
14	23.13	94.3
15	27.30	82.3
16	24.33	97.3
17	26.90	82.7
18	23.73	83.7

TABLE 3

Precipitation

(In millimeters)

July 1945: Date	22–2 hours	2–6 hours	6–10 hours	10–14 hours	14–18 hours	18–22 hours	Total
10	------	------	------	------	6.4	0.1	6.5
11	------	------	------	------	0.1	0.0	0.1
12	3.4	6.3	113.7	49.2	41.4	11.3	225.3
13	3.1	0.0	------	------	------	------	3.1
14	------	0.1	0.0	7.2	25.9	0.0	33.2
15	------	------	------	------	------	------	------
16	------	------	0.2	20.0	8.9	------	29.1
17	0.0	0.0	1.5	1.4	3.9	4.6	11.4
18	0.9	------	------	------	------	------	0.9

TABLE 2

Wind Direction and Velocity

[Legend: 4-h: Hour readings; Dir.: Wind direction; MPS: Meters per second velocity; MPH: Miles per hour velocity.]

Date July 1945	2–h			6–h			10–h			14–h			18–h			22–h			Hours average	
	Dir.	MPS	MPH	Dir.	MPS	MPH	Dir.	MPS	MPH	Dir.	MPS	MPH	Dir.	MPS	MPH	Dir.	MPS	MPH	MPS	MPH
16	-----	0.0	0.0	SW	1.5	3.35	ENE	1.7	3.8	NNW	3.0	6.7	E	1.3	2.9	----.	0.0	0.0	1.5	3.35
17	S	3.7	8.27	W	2.0	4.49	WSW	3.2	7.15	SW	4.8	10.7	SW	1.8	4.0	NE	2.5	5.59	3.10	6.93

TABLE 4

Sunshine

(Jordan Type Meter)

Date July 1945:	Percent of hours													
	6–7h	7–8h	8–9h	9–10h	10–11h	11–12h	12–13h	13–14h	14–15h	15–16h	16–17h	17–18h	18–19h	Total
10	0.05	0.10	0.00	0.20	0.00	0.00	0.30	0.30	0.00	1.00	0.80	0.60	0.30	3.65
11	0.00	0.22	0.67	0.68	0.40	0.20	0.00	0.04	0.00	0.20	0.00	0.00	0.00	2.41
12	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
13	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	1.00	0.55	12.55
14	0.30	0.10	0.50	0.90	0.50	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	2.30
15	0.00	0.00	0.20	1.00	0.90	0.60	0.40	0.62	1.00	0.40	1.00	1.00	0.30	7.42
16	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.07	0.10
17	0.00	0.00	0.05	0.60	0.50	0.20	0.00	0.00	0.00	0.00	0.00	0.00	0.00	1.35
18	0.05	0.00	0.00	0.00	0.00	0.01	0.30	0.05	0.00	1.00	0.70	0.20	0.15	2.46

TABLE 5

Damage Analysis

Offices and Banks

Building No.	Function	Fire class	Plan area	Usable floor area	Square feet of damage			
					Structural	Superficial	Minor	Contents
			Sq. Ft.	*Sq. Ft.*				
5	Bank	C	5,200	10,400	5,200			10,400
6	Bank	C	1,600	3,200				
7	Post office	C	1,200	2,200				
8	Dispensary	C	1,200	3,228				
11	Police headquarters	C	4,850	9,700				
12	Prefecture	C	21,900	43,800	2,200	7,000	7,000	7,000
13	Bank	C	1,650	3,300				
15	Bank	C	1,800	3,600			200	360
16	Bank	C	6,700	13,400	6,700	13,400		13,400
18	Insurance company	C	1,200	2,400				
10[1]	Totals	C	47,300	95,228	14,100	20,400	7,200	31,160

[1] Number of buildings.

Offices and Banks

Building No.	Function	Fire class	Plan area	Usable floor area	Square feet of damage			
					Structural	Superficial	Minor	Contents
			Sq. Ft.	*Sq. Ft.*				
9	Bank	R	2,700	3,400			100	
10	Bank	R	12,400	24,800			300	400
17	Telephone exchange	R	9,600	19,200				
19	Police station	R	3,400	6,800				
4[1]	Totals	R	28,100	54,200			400	400

[1] Number of buildings.

Schools and Churches

Building No.	Function	Fire class	Plan area	Usable floor area	Square feet of damage			
					Structural	Superficial	Minor	Contents
			Sq. Ft.	*Sq. Ft.*				
1	Church	C	2,400	3,600			10	
20	Grade school	C	15,000	25,000	25,000			25,000
21	Girls school	C	42,000	50,000	50,000			50,000
3[1]	Totals	C	59,400	78,600	75,000		10	75,000

[1] Number of buildings.

Commercial

Building No.	Function	Fire class	Plan area	Usable floor area	Square feet of damage			
					Structural	Superficial	Minor	Contents
			Sq. Ft.	*Sq. Ft.*				
4	Store	R	1,100	2,200			2,200	2,200
14	Department store	R	10,000	45,000			3,000	25,000
2[1]	Totals	R	11,100	47,200			5,200	27,200

[1] Number of buildings.

Industrial

Building No.	Function	Fire class	Plan area	Usable floor area	Square feet of damage			
					Structural	Superficial	Minor	Contents
			Sq. Ft.	*Sq. Ft.*				
2	Confectionery manufacturing and storage.	R	1,800	3,600				1,800
3	Sauce factory	R	3,840	7,680			3,840	7,680
2[1]	Totals	R	5,640	11,280			3,840	9,480

[1] Number of buildings.

Damage Analysis Recapitulation

Number of buildings	Function		Plan area	Usable floor area	Square feet and percentage of damage							
					Structural		Superficial		Minor		Contents	
					Sq. Ft.	%	Sq. Ft.	%	Sq. Ft.	%	Sq. Ft.	%
			Sq. Ft.	*Sq. Ft.*								
10	Offices, banks	C	47,300	95,228	14,100	14.8	20,400	21.4	7,200	7.6	31,160	32.7
4	Offices, banks	R	28,100	54,200					400	0.7	400	0.7
3	Schools and churches	C	59,400	78,600	75,000	95.4			10	0.013	75,000	95.4
2	Commercial	R	11,100	47,200					5,200	11.0	27,200	57.6
2	Industrial	R	5,640	11,460					3,840	33.5	9,480	82.7
21	All included	C & R	151,540	286,688	89,100	31.08	20,400	7.11	16,650	5.8	143,240	49.96

Part 3

EFFECTS OF INCENDIARY BOMB ATTACKS ON TOKYO, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 67

II. SUMMARY 67

III. GENERAL INFORMATION 67

IV. THE TARGET 68

V. ATTACK DATA 87

VI. ANALYSIS OF DAMAGE 94

VII. CONCLUSIONS 116

Photographs 1-58, inclusive

Figures 1-3, inclusive

Table 1

I. Object of Study

The primary purpose of this study was to determine why the incendiary bomb attack of 9-10 March 1945 by the Twentieth AF on the densely populated Incendiary Zone 1 of Tokyo was so highly successful. The purpose was further to appraise the fire damage to industrial establishments caused by direct hits and by exposure fires. In addition, the other major attacks on Tokyo are listed to give a more complete picture of the effort directed against the city and the damage accomplished.

II. Summary

1. Tokyo, included in the world's third largest metropolitan area, had a population of more than 7,000,000 in 1944. It was the seat of the national government and the leading city of Japan in manufacturing, commerce, communication, transportation, and amusements. The metropolitan area of Tokyo covered more than 800 square miles; the city proper, more than 200 square miles; and the highly built-up portion of the city, about 100 square miles.

2. Tokyo Incendiary Zone 1 was the most highly built-up portion of the city and its 11.08 square miles had an average built-upness of more than 40 percent. (Built-upness is a measure of the portion of an area covered by buildings.) Its population density ranged from 90,000 to more than 135,000 persons a square mile and averaged 103,000.

3. More than 95 percent of the buildings in Zone 1 were wooden and of typical Japanese construction. Most of these buildings had tile roofs, but some had corrugated sheet-metal roofs. They were normally built in solid block fronts separated by narrow alleys 10 to 15 feet wide. Wide streets separated these into sections of 50 to 100 blocks. The total length of firebreaks in this zone was 78 miles.

4. Home industry was highly concentrated in Zone 1 which was also surrounded on three sides by factory areas. Most of the people living in the zone worked either in the home industries or in the surrounding factories.

5. When it became evident that the city would be subjected to air attacks the Japanese prepared firebreaks 120 to 300 feet wide through the densely built-up areas by razing buildings. Thousands of structures were demolished for this purpose before the end of the war. Fire equipment was increased to a total of 1,117 pieces, of which 716 were motor-driven pumpers with capacities of 350 to 500 gallons per minute. In addition, numerous pieces of hand-operated equipment were distributed throughout the city, and an effort was made to instruct the people in their use. The normal fire department strength of 2,000 was increased to 8,100. Practically all firemen were required to go through a school of instruction. By Japanese standards they were considered well trained, but by American standards they were still in the recruit stage.

6. The source of water was ample for the city, but the scant distribution system was inadequate from a fire-protection standpoint. More than half of all pipes were three or four inches in diameter. Pressures were generally low, varying from zero to 25 pounds per square inch. Sixty percent of all hydrants were one-way flush type on 4-inch or smaller mains. A few static tanks of 20,000- to 40,000-gallon capacity had been built, but they were not in sufficient number to be effective.

7. Six attacks are considered in this report. The most important of these was the night attack of 9-10 March 1945, both because this attack marked the departure from high-altitude daylight bombing in formation to individual low-level night bombing, and because the efficiency of this attack was greater than any made before or since. In this attack 9.48 square miles of the target were burned for each 1,000 tons of bombs dropped (or 1 square mile per 105 tons). A total of 15.8 square miles of the city was totally or heavily damaged in this attack; 56 square miles were totally or heavily damaged in all attacks. One other attack, that of 25-26 May 1945, damaged a greater area, 16.8 square miles, but the bomb tonnage dropped was twice as great.

8. The number of persons made homeless by all attacks on Tokyo totaled 2,861,857 (1,008,000 by the attack of 9-10 March). All attacks killed 95,972 persons (83,793 in the attack of 9-10 March).

III. General Information

1. The portion of Tokyo Area Team 6 which

conducted this investigation consisted of the following personnel:

Maj. G. P. Guill	Team chief.
Maj. T. F. Gallagher	Ordnance.
Maj. H. V. Keepers	Fire damage analyst.
1st Lt. J. S. Raines	Fire damage analyst.
PhoM 2/c J. D. Devore	Photographer.
T/4 M. Shimomura	Interpreter.
Cpl. H. L. Born	Draftsman.

2. The study was conducted during the periods 27 October-1 November and 20 November-28 November 1945. The weather during the latter period was cold and rainy, making it difficult to obtain good photographs.

3. Information for this report was obtained from the chief of the Tokyo fire department, various plant managers, police, firemen, residents, and other divisions of the Survey. Information from Japanese sources was usually verified by examination or by questioning several individuals on the same subject, although there seemed to be no reason why false information should be given deliberately by the Japanese. Cooperation by all concerned was excellent. The photo cover for the attack of 23-24 May was too poor to be used in making a good damage estimate. The figure for the damage in that attack used in this report was obtained by measuring the damage plotted on a map by the Japanese immediately following the attack. Excellent photo cover was available for the combination of this attack and the attack of 25-26 May, and the damage from the latter attack was taken as the difference between the combination from photo cover and the former from Japanese sources.

IV. The Target

1. Tokyo was part of a vast metropolitan area located along the north shore of Tokyo Bay and situated in the southeast corner of the Kanto plain. This metropolitan area which included Tokyo, Yokohama, Kawasaki, and numerous small suburban villages was the third largest in the world before the air attacks began. The city of Tokyo proper was the largest city in Japan, its population of 7,238,569 (1944 census) having been as great as the five next largest cities of Japan combined. Tokyo was the seat of the national government, the home of the emperor and the imperial court and the center of power and authority. It was at once the greatest industrial, communications, transportation, commercial, and amusement center of Japan. It was also considered to be preeminent in respect to universities, museums, hospitals, department stores, office buildings, and theaters.

2. The Metropolitan District of Tokyo formed an irregular oval extending some 28 miles from north to south and 57 miles from east to west, totaling 828 square miles. The 35 wards of the city proper covered only one-fourth of the Metropolitan District (213 square miles), but contained more than 90 percent of its population. Of the city proper an area of 103.45 square miles was highly built up, and for this reason it was considered by the United States Air Forces as the Tokyo target area. This area consisted of:

	Square miles
Incendiary Zone 1	11.08
Incendiary Zone 2	57.04
Target Area 90.17-3600	8.52
Target Area 90.17-3601	14.85
Target Area 90.17-3602	6.70
Target Area 90.17-3603	5.26
Total	103.45

Figure 1 shows the location of Incendiary Zone 1.

3. The largest and best buildings in Tokyo were located east of the imperial palace (Photo 1) in the financial and shopping districts (Marunouchi and the Ginza). There were many multi-story, earthquake-and-fire-resistive buildings, but these were interspersed with flimsy wood structures. The better residential areas extended from the palace grounds well into the northwestern and southwestern sections of the city. Although most of the streets in these sections were narrow, the built-upness was not so great as in other sections of the city, and the houses were often surrounded with walled gardens. The principal open spaces were parks totaling some seven square miles.

4. Since the primary object of this report is concerned with Mission 40, the 9-10 March attack, a somewhat detailed description of Incendiary Zone 1 follows. The facts presented

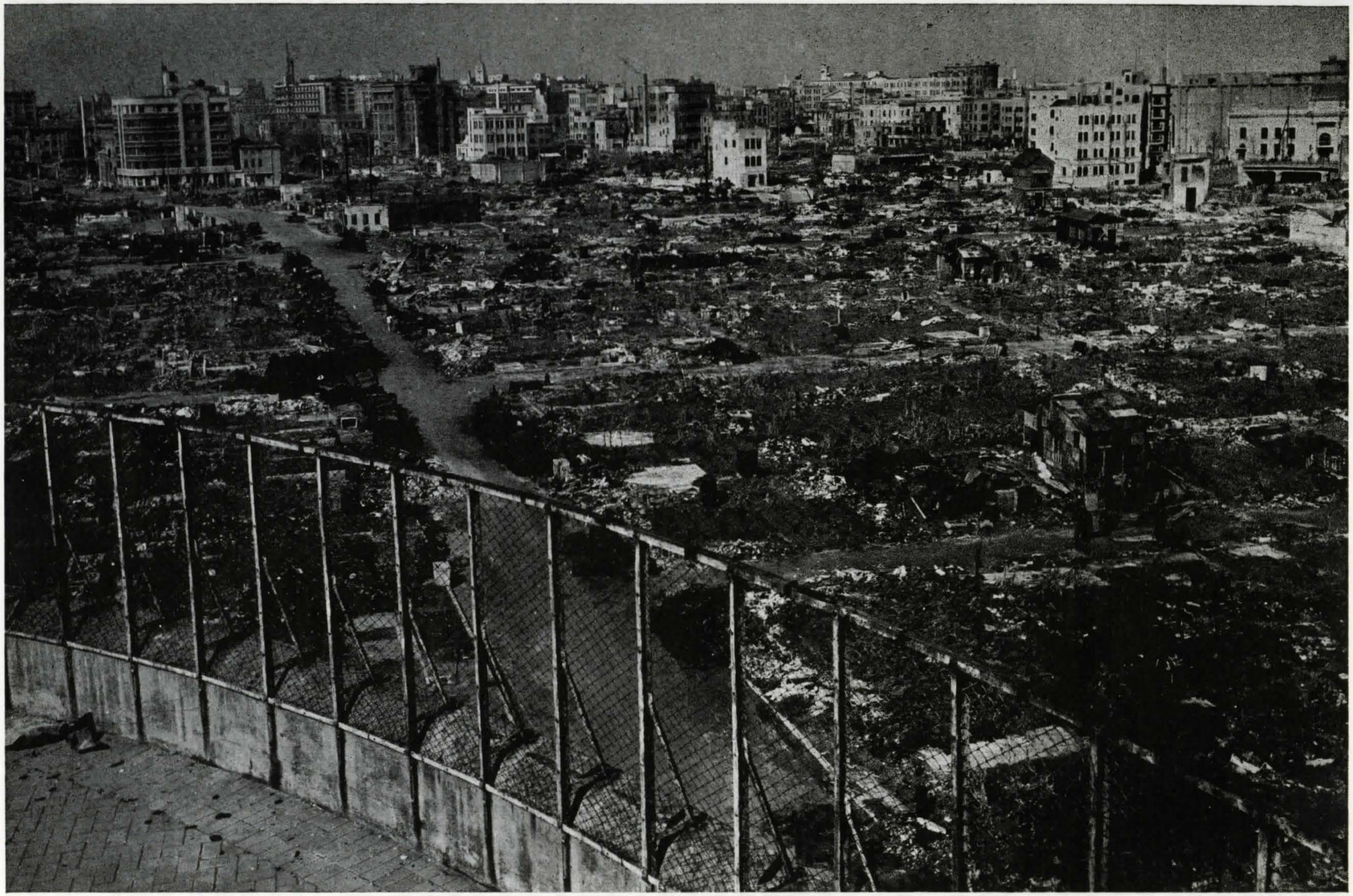


Photo 1.—Looking toward the shopping and financial districts of Tokyo. This section contained the modern fire-resistive structures of the city. Note the bareness of the burned-out section in the foreground on which typical Japanese structures formerly stood. Also note the burned vehicles caught in the street.

would have applied in general to the rest of Tokyo.

a. The target area chosen for Mission 40 was Incendiary Zone 1, a highly congested, rectangular-shaped area approximately three miles east-west by four miles north-south (Figure 1). The conspicuous imperial palace grounds lay at the southwest corner, and the western boundary extended northward to Ueno Park, another prominent open space about two miles north of the palace. The boundary then curved to the east and north along the Joban railroad to the Sumida River, thence southeast to a north-south line, the eastern boundary, which was halfway between the Sumida River and the Diversion Canal. The southern boundary extended from this line due west across the **Y**-mouth of the Sumida River to the palace grounds. The western boundary of Zone 1 bordered on Tokyo's business center, extending north and south along the east side of the imperial palace grounds. Included in this area was the Ginza (shopping area) with its numerous shops and fine department stores. The Marounouchi Section, near the palace, contained government buildings, banking houses, newspaper plants, and insurance company buildings. The north boundary adjoined Tokyo's great arsenal area and railroad marshalling yards. The eastern boundary, extending through the center of the island made by the Sumida River and the Diversion Canal, bordered on a large industrial area of steel mills, instrument plants, foundries, spinning mills, and numerous miscellaneous industrial plants on the canals in this area. The southern boundary bordered on an area of heavy industry, including shipyards along Tokyo Bay. The near-by industrial area drew heavily on the population of Zone 1 for labor.

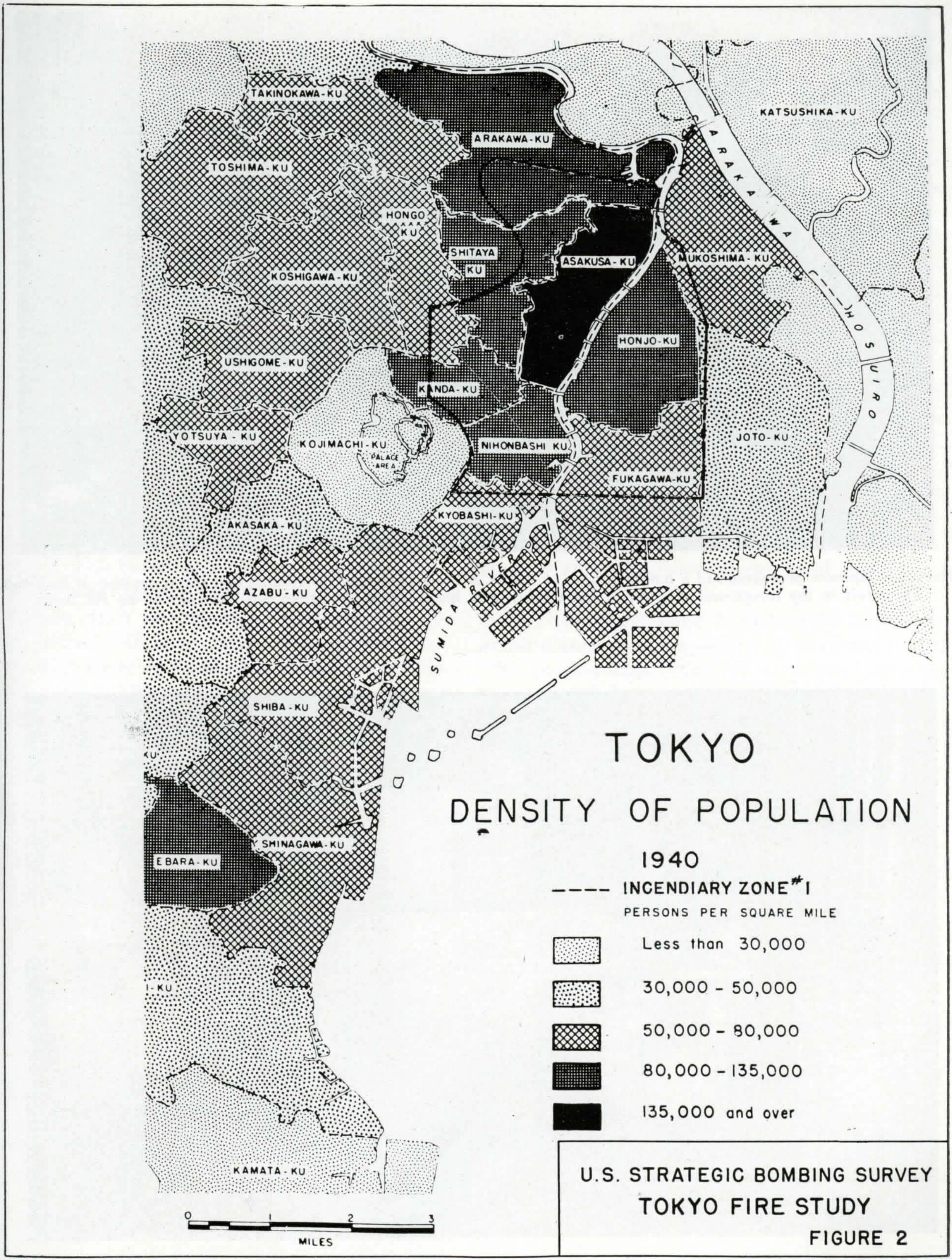
b. Zone 1 included one of the most densely populated areas in the world—Asakusa Ku with a population of more than 135,000 persons per square mile. The remainder of the zone had a population density of 80,000-135,000 persons per square mile except for a small portion in the southeast corner where the population was somewhat less (Figure 2). Average population density was 103,000. The total number of persons living within the area was estimated at 1,100,000 or about 15 percent of Tokyo's population. Most of the persons made their living from the industries in and surrounding this area.

c. There was probably no other residential area in the world of a comparable size which equaled the built-upness of Zone 1, which averaged 40 to 50 percent. This means that the roof area of the zone was 40 to 50 percent of the total area, including streets, small parks and rivers, and all other areas within its boundaries (Photo 2). When it is considered that the average American residential area is only about 10 percent built up, it can be seen that Zone 1 was highly congested.

d. After the earthquake and fire of 1923, Tokyo was largely rebuilt, but many temporary wooden barracks were erected to meet the emergency. In Zone 1 a large number of these barracks had degenerated into permanent slum areas instead of being replaced as had been originally planned.

e. There were six important targets within Zone 1, the most important of which was the Hattori Co., peacetime manufacturers of Seikosha watches, and wartime manufacturers of fuzes for artillery shells. The remaining targets were railroad yards, stations, and market areas. The heavy industrial area was just east of the eastern boundary of Zone 1 and included some 35 important targets. Shipyards, steel mills, and cable plants were along the southern boundary of Zone 1. Principal strategic products were fuzes, steel and special alloys, copper wire and cable, bakelite, electric motors and allied products, textiles, guns, railroad rolling stock, and numerous small parts for aircraft and automobiles. The importance of this area to the total output of strategic war products was indicated by the special efforts made to protect the plants from possible incendiary attacks. They were surrounded by 100-foot firebreaks, and special efforts were made to train fire brigades. In some instances the Tokyo fire department maintained a fire station on the premises.

f. This target area of Tokyo was ideal for home industry which was prevalent in all large Japanese cities. The feeder factories were near the workers' homes, which solved the problem of transportation of raw materials to the home and finished products back to the factory. Small machined parts and foodstuffs were the



U.S. STRATEGIC BOMBING SURVEY
TOKYO FIRE STUDY
FIGURE 2

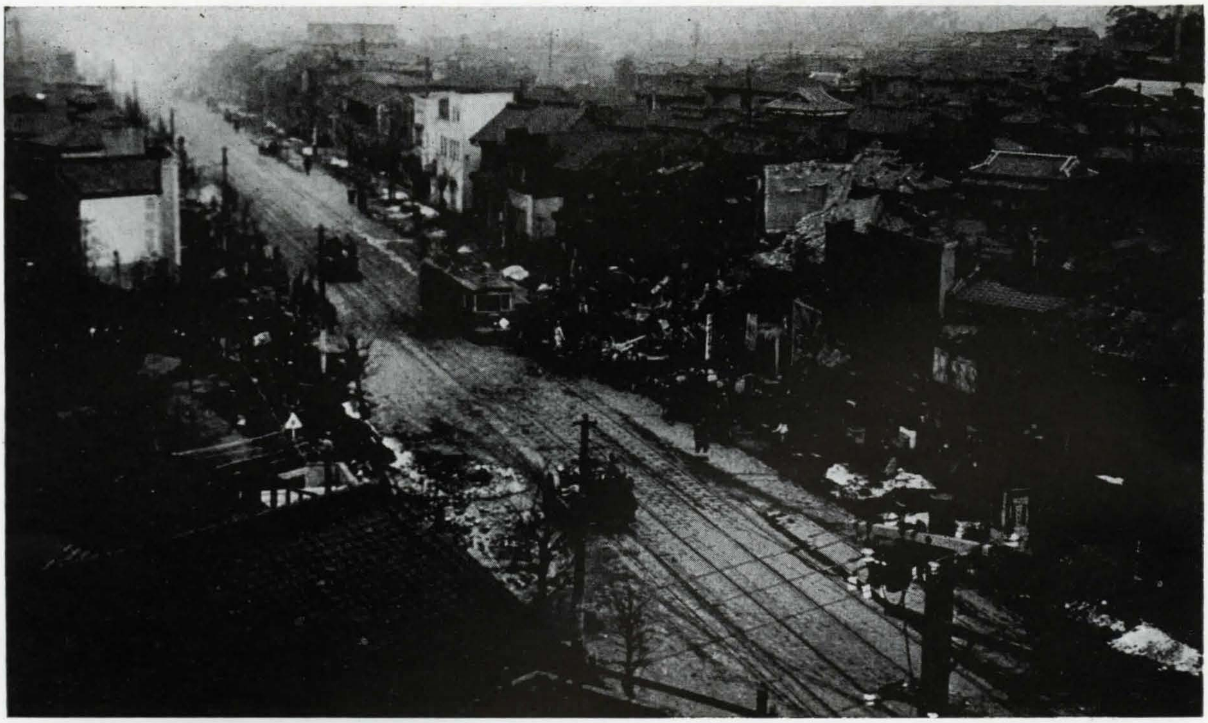


Photo 2.—Japanese photograph of a typical section of Tokyo in Zone 1 showing the construction and congestion of buildings. The street in the foreground was one of the widest. The house across the street was damaged by an HE bomb.

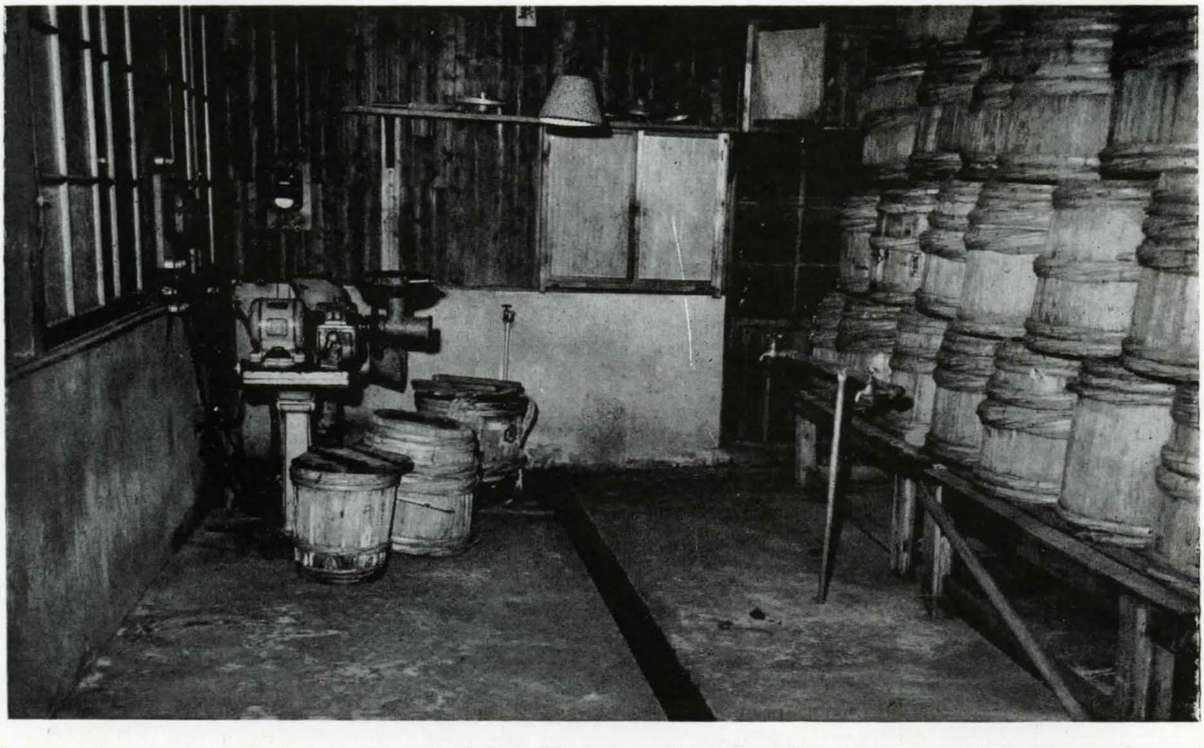


Photo 3. — Interior view of a home industry food plant. Note exposed wiring. This plant was much less cluttered up with loose inflammable items than were the majority.

principal products (Photos 3, 4, 5). These small producers were located both in homes and in small shops formerly devoted to other uses. The number of such establishments is not available, but it is known that they were very numerous and contributed heavily to the output of the larger plants. Burned machinery of these home industries was noted throughout the area.

g. Dwellings in this zone were typically Japanese (Photos 6 and 7). For the most part, they were two-story wood-frame (Photos 8 and 9) with ½- to ¾-inch wood floors covered with straw tatami mats, and with tile on (mud-fill) wood roofs. The ceilings were of unprotected ¼-inch wood laths. In many cases the first floor was used for a small store or some home industry. Small charcoal braziers (Photo 10) were the only means of heating the houses. Cooking was accomplished on a similar device, usually of stone or clay built as an integral part of the building. Most Japanese homes had no basement. Framing in the usual dwelling was approximately four by four inches for studs, with intermediate members two by four inches. Outside walls were covered by thin clapboards or bamboo lath and low-grade mud plaster. Framing members were joined by mortise-and-tenon joints with very few nails or other metal parts used in the construction (Photo 7).

h. The combustibility of Japanese dwellings was well illustrated by tests made in this country. Four buildings were constructed: two in the "typical Japanese fashion" with outer walls of clapboard and with exposed windows (the combination store-residence type so common in Zone 1) ; and the other two to comply with the latest Tokyo fire regulations. The latter were two stories high with ¾-inch plaster on metal reinforcing (lath) and with wooden shutters on windows. The four structures were set on fire to determine the time necessary for their destruction. Those constructed in "typical Japanese fashion" burned to the ground in 12 minutes; those constructed in accordance with Tokyo fire regulations were consumed in 32 minutes. It was estimated from unburned areas of Tokyo near Zone 1 that about 95 percent of the dwellings were built in "typical Japanese fashion."

i. There were few modern apartment buildings in Tokyo. Those inspected were usually 4- to 5-story, fire- and earthquake-resistive structures, built after the 1923 earthquake. All were located in congested areas and were susceptible to exposure fires. None of those inspected, however, was provided with exposure protection devices such as wire-glass windows and fire shutters.

j. The majority of manufacturing plants were one-story, masonry, or steel-frame structures with wood-frame or unprotected-metal roof trusses. (Tokyo was subject to numerous earthquakes and the construction of multistory, earthquake-resistive buildings was prohibitive in cost.) Roof covering was either corrugated iron or asbestos cement. Masonry walls were widely used in the spinning and weaving mills, instrument (electrical) plants, printing plants (converted to other uses), or similar industrial establishments. Steel-frame structures were commonly used in foundries, steel plants, machine shops, and analogous industries.

k. Throughout Zone 1 there were numerous small plants, each employing 50 persons or less. The predominant type of structure housing these industries was of wood or steel frame with a roof covering of corrugated iron or asbestos cement (Photo 11). These plants were all seriously exposed by surrounding dwellings and mercantile buildings.

l. The street pattern of Tokyo followed a fairly definite plan. Individual blocks were bounded by narrow alleys, hardly more than 12 feet wide (Photo 12). Groups of blocks varying in number from 100 to 300 were bounded by wide thoroughfares or canals 100 feet in width on the average (Photo 13). Sections along the east bank of the Sumida River were (more or less) square in shape, while the territory west of the river was irregular in pattern and size. Due to the highly combustible structures and narrow alleys, these sections were the smallest units that could be considered as individual fire areas. It would be possible under peacetime conditions to halt the spread of fire across one of the wide streets with a well-trained and well-equipped fire department, because brands falling on tile roofs do not spread fire. The narrow alleys made it difficult to move any but the

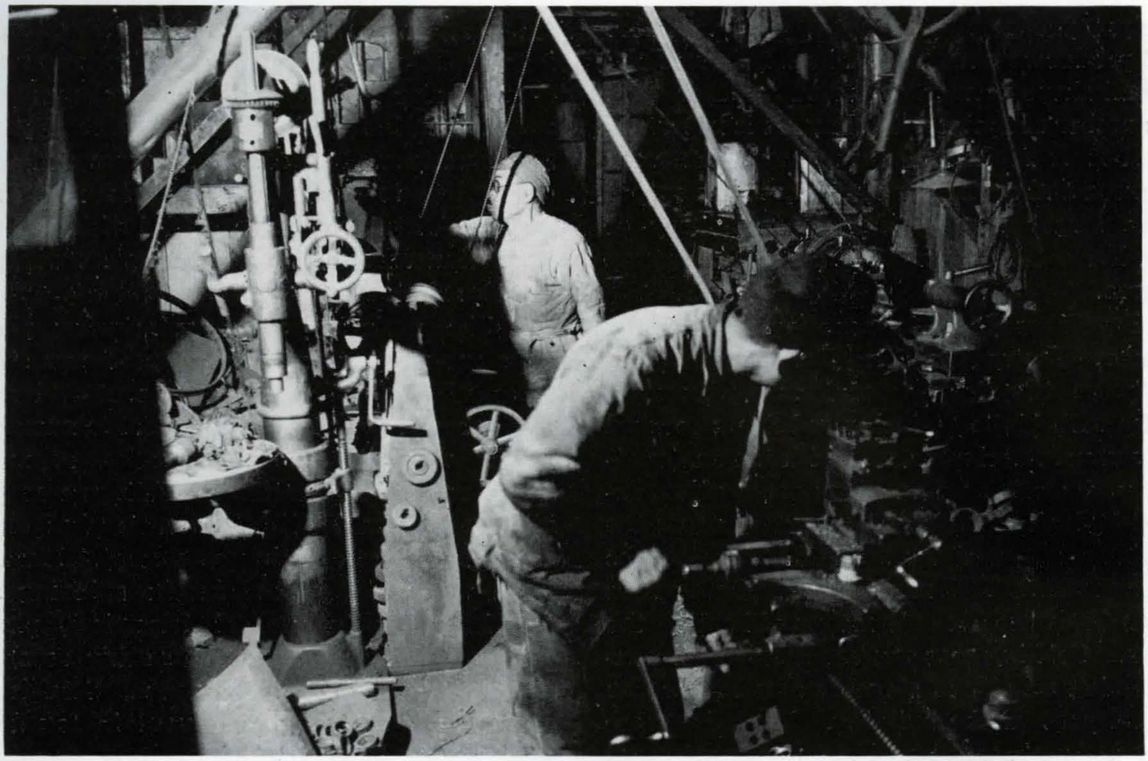


Photo 4.—Typical Japanese home industry machine shop showing crowded conditions and combustibility.

Photo 5.—Typical Japanese home industry machine shop showing roof construction and crowded pulley arrangement.

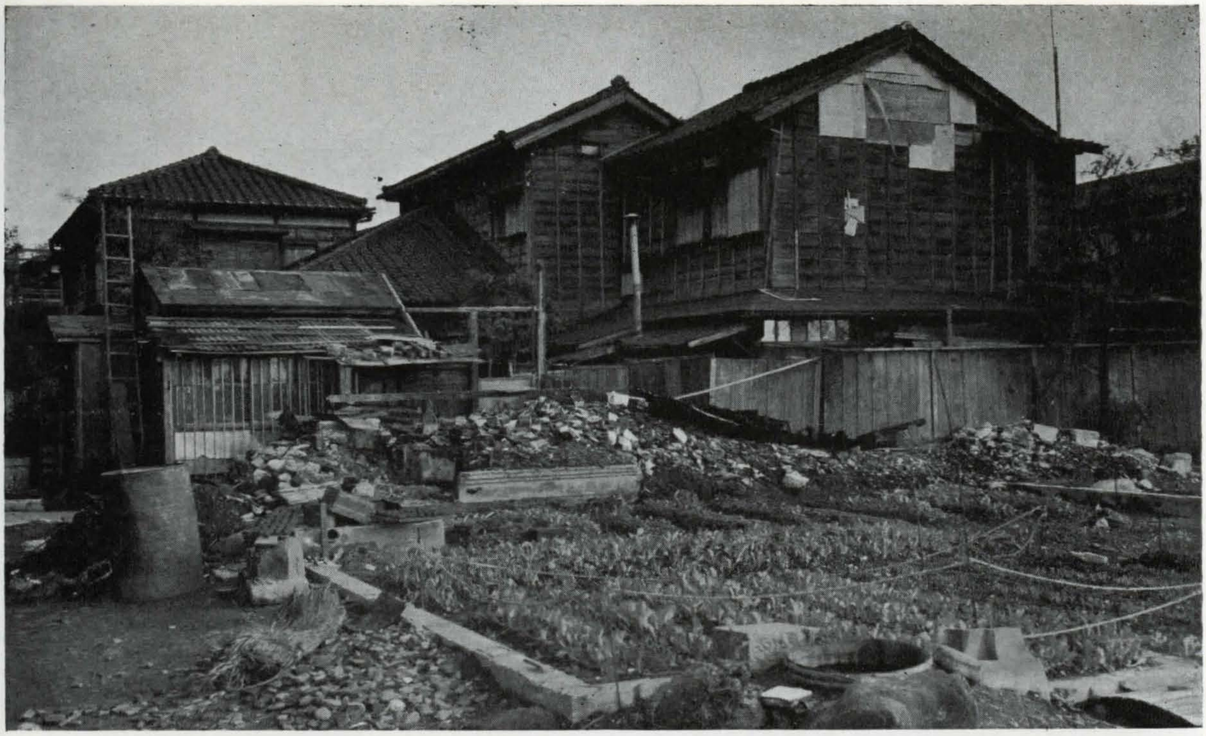


Photo 6. — Typical Japanese homes with thin clapboard sides and tile roofs. The garden in the foreground was planted inside the foundations of a house wrecked to form a firebreak.

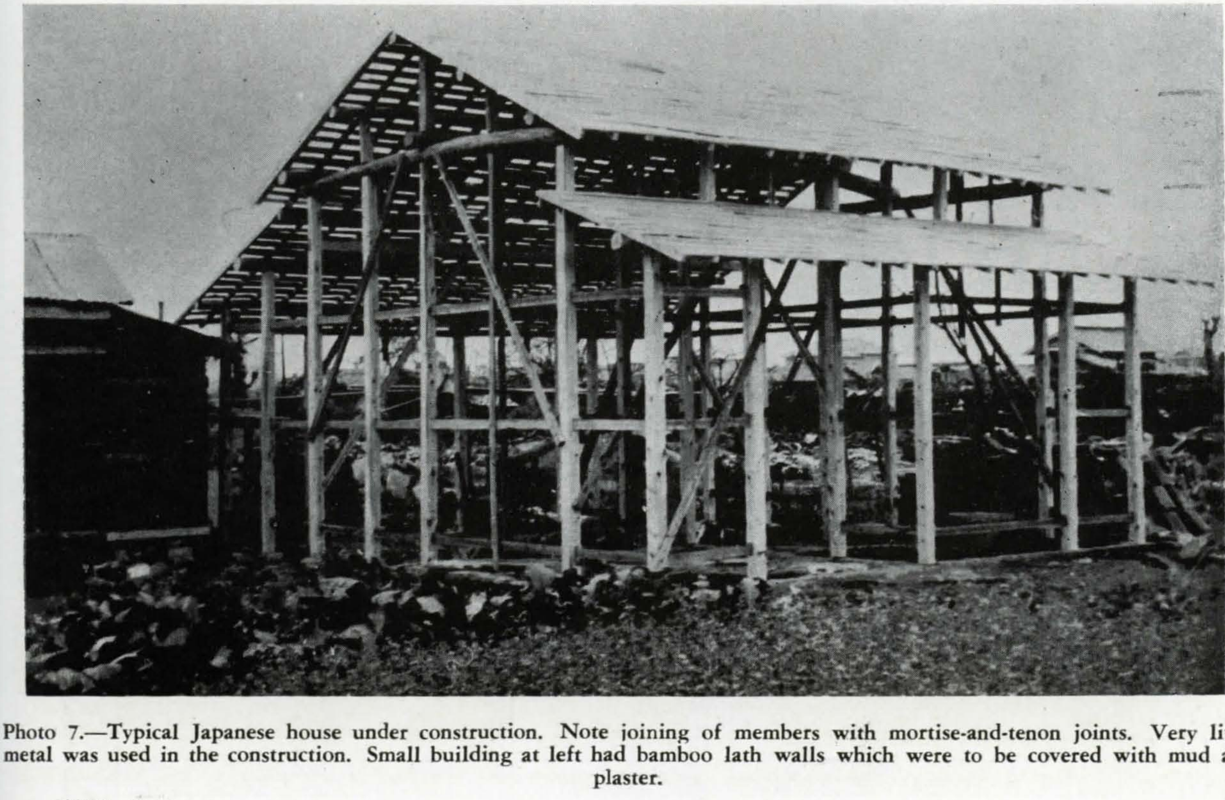


Photo 7.—Typical Japanese house under construction. Note joining of members with mortise-and-tenon joints. Very little metal was used in the construction. Small building at left had bamboo lath walls which were to be covered with mud and plaster.

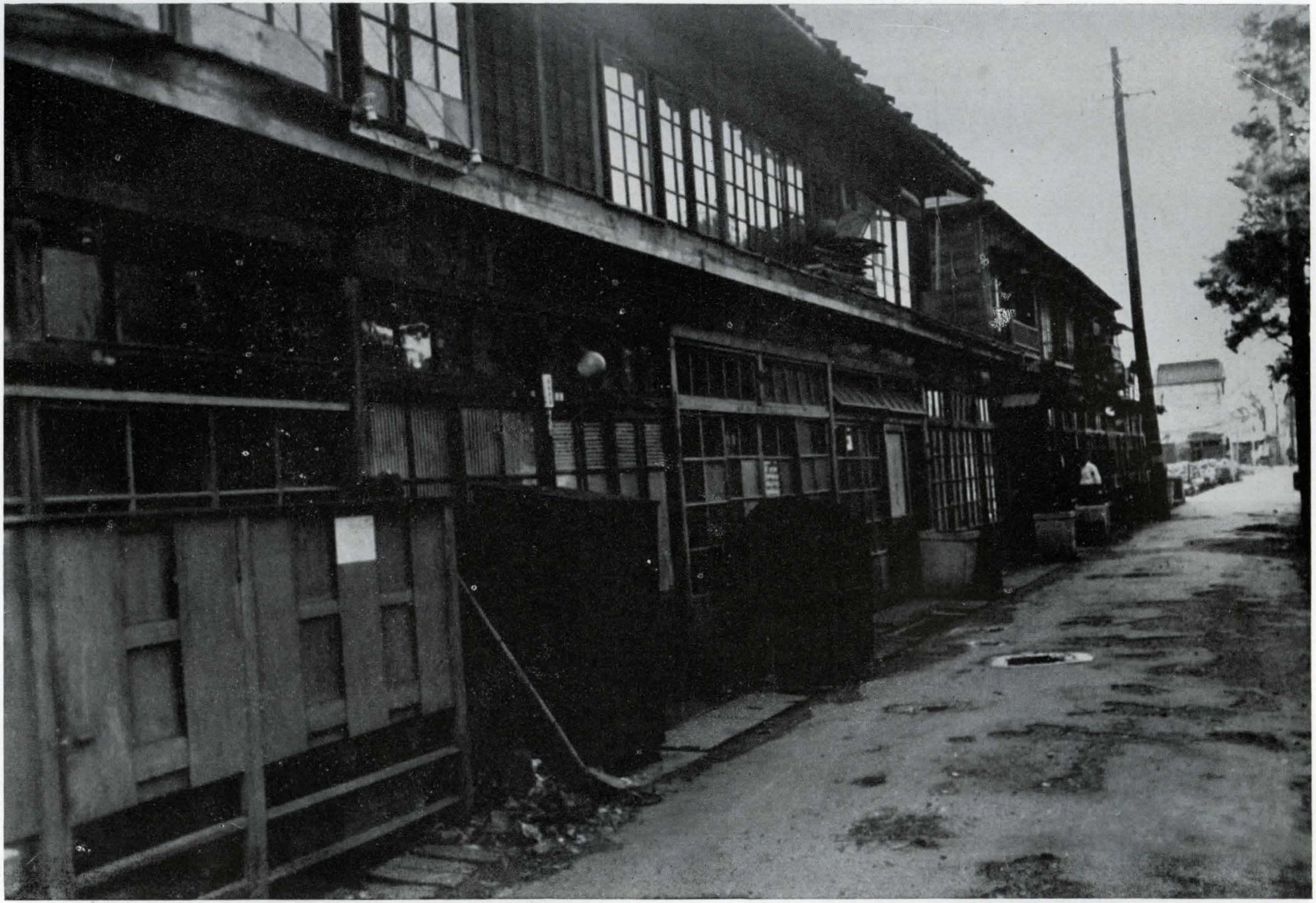


Photo 8.—Typical combination dwelling and shop buildings in solid block front without intervening fire walls. Observe the small static water tanks at the far end.

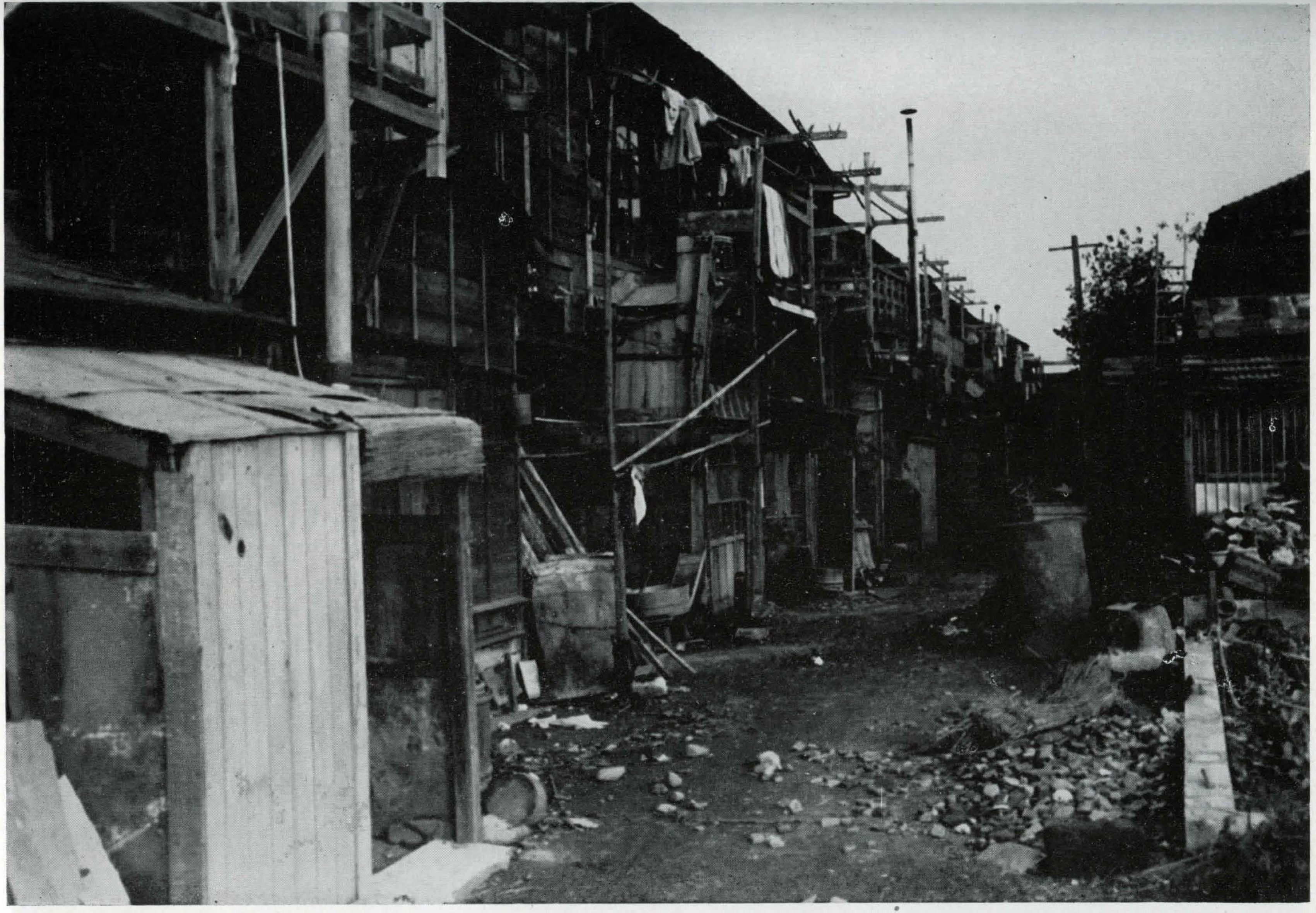


Photo 9.—Interior of block showing rear of buildings in Photo 8. Note the flimsy construction and narrow alley.

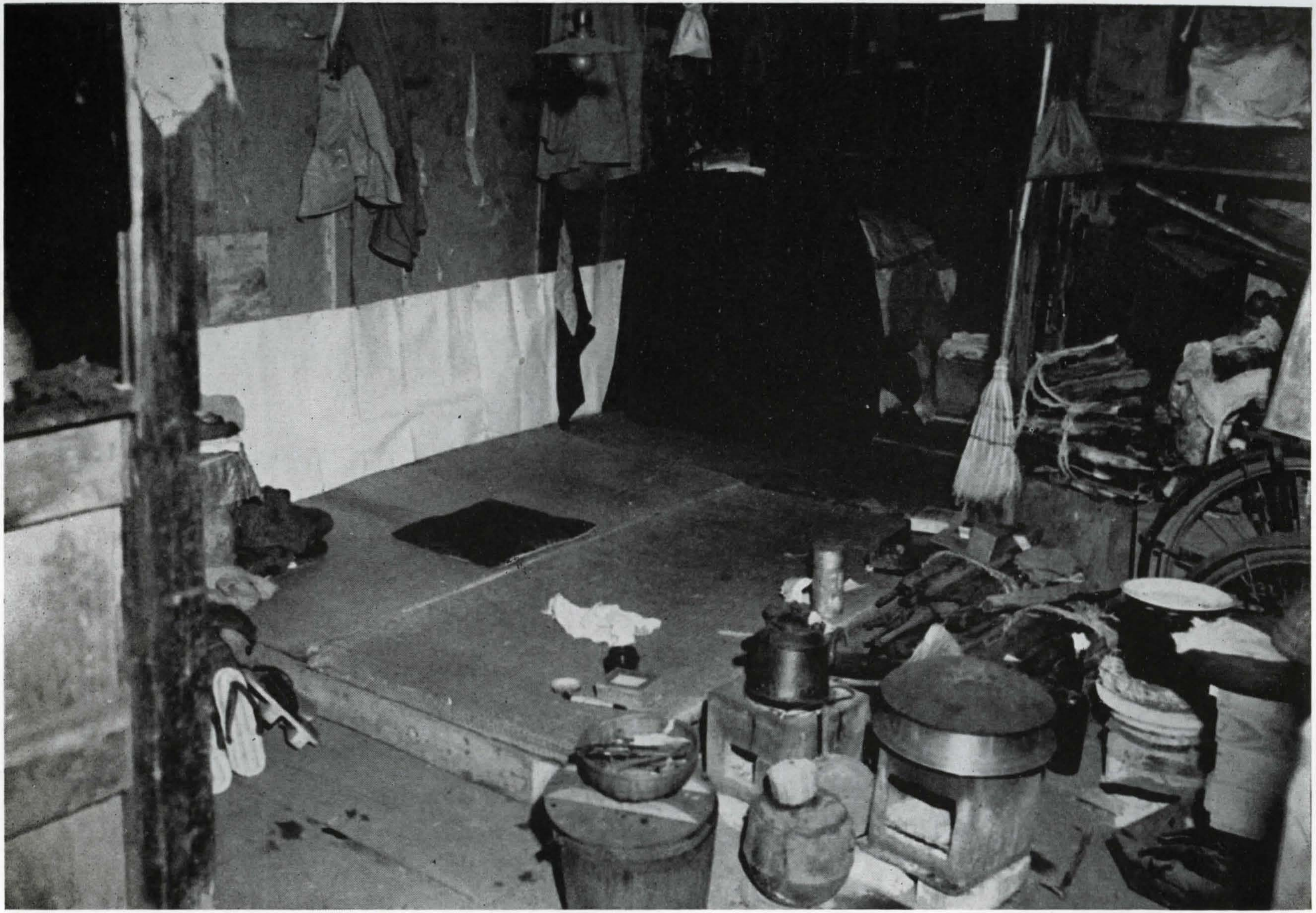


Photo 10.—Interior of low-class dwelling. Note the straw mat floor covering, the charcoal braziers, and the general accumulation of highly inflammable material

smallest pieces of fire equipment within the individual sections. Thus the conflagration hazard from a large area incendiary bomb attack was serious. In view of the above, it is apparent that the starting of numerous fires on both sides of firebreaks and wide streets would be more than the local householders could combat and would be too numerous for the fire department personnel to handle. This together with the highly combustible, flimsy, quick-burning construction would defeat the efforts of the best of fire departments.

m. The purpose of firebreaks is to confine fires within certain limits and provide avenues of escape for the people. These firebreaks may be blocks of fire-resistive structures forming a solid wall at right angles to the source of the fire, or open spaces of land, canals, rivers, or widened streets made by removing buildings. Tokyo, like other Japanese cities, had many transportation canals. Where they were 100 feet or more in width, these canals made excellent firebreaks. Several wide canals were located west of the Sumida River and east of the imperial palace. The Sumida River was the most effective firebreak in Zone 1. It divided the Zone almost in half from northeast to southwest. In April 1944 the Japanese Government realized that the Home Islands might be subject to heavy air attacks and took steps to lessen the danger of fire spread by creating man-made firebreaks. From this time until the end of the war thousands of buildings were removed or demolished for this purpose (Photo 14). From east to west the breaks were 120 to 300 feet wide, since the prevailing winds were north-south except in summer months. A notable exception was a 300-foot break running north to south near the eastern boundary of Zone 1. With the natural barriers of canals and rivers, these firebreaks with the assistance of an adequate fire department would have kept a peacetime fire confined to the area of origin. The incendiary bomb attacks, however, nullified their effectiveness by starting fires on both sides of them. Statistics on fire breaks in Zone 1 are given below:

Firebreaks

	150 feet wide or more	65-150 feet wide	Total
Total length (miles)	26.3	51.7	78.0
Subjected to fire (miles)	20.6	37.3	57.9
Percentage subjected to fire	78.3	72.1	74.2
Fire stopped (miles)	3.6	2.3	5.9
Percentage stopped	17.4	6.1	10.1

NOTE—Fires were considered "stopped" where incendiary damage existed directly on one side of a firebreak only. This is, therefore, a minimum assessment of efficiency, because fires on both sides were often caused by bombs falling on both sides and not by fire spread.

n. Fire departments in Japan were administered from the ministerial level though the police bureau of the Minister of Home Affairs. In Tokyo the fire chief was appointed directly by the Minister of Home Affairs with the sanction of the emperor. In this manner the fire department came under the direct control of the police department with the result that many inexperienced men from the police department were given positions in the fire department. The actual operating heads of the various units of the fire department were usually well educated men of long experience.

(1) Personnel was generally well selected with emphasis on personal fitness, but wartime drain on fire department personnel made it necessary to relax these restrictions. When it became apparent that Allied forces were approaching closer to the Home Islands an intensive campaign to increase the size of the department was made. The normal strength of the Tokyo fire department, about 2,000, was increased to 8,100, including 2,700 active junior firemen. The ultimate goal of 12,500 was never reached, and at the time of the survey, the actual strength was 6,610 men.

(2) The work periods were definitely set out in regulations, but, during the closing days of the war, the man-power shortage and the numerous air-raid warnings allowed few firemen to spend more than an hour or two a day away from the stations. During the war the recruit training period was reduced to 30 days and included the same routine as the regular school but with less time devoted to practice. All drills were under the direction of instructors especially selected for their ability. The training period compared favorably to the time devoted to that purpose in the United States, but the subjects covered were elementary from a fire-protection standpoint. The severe shortage of fire-fighting equipment made it necessary to use dummy or immobilized equipment for

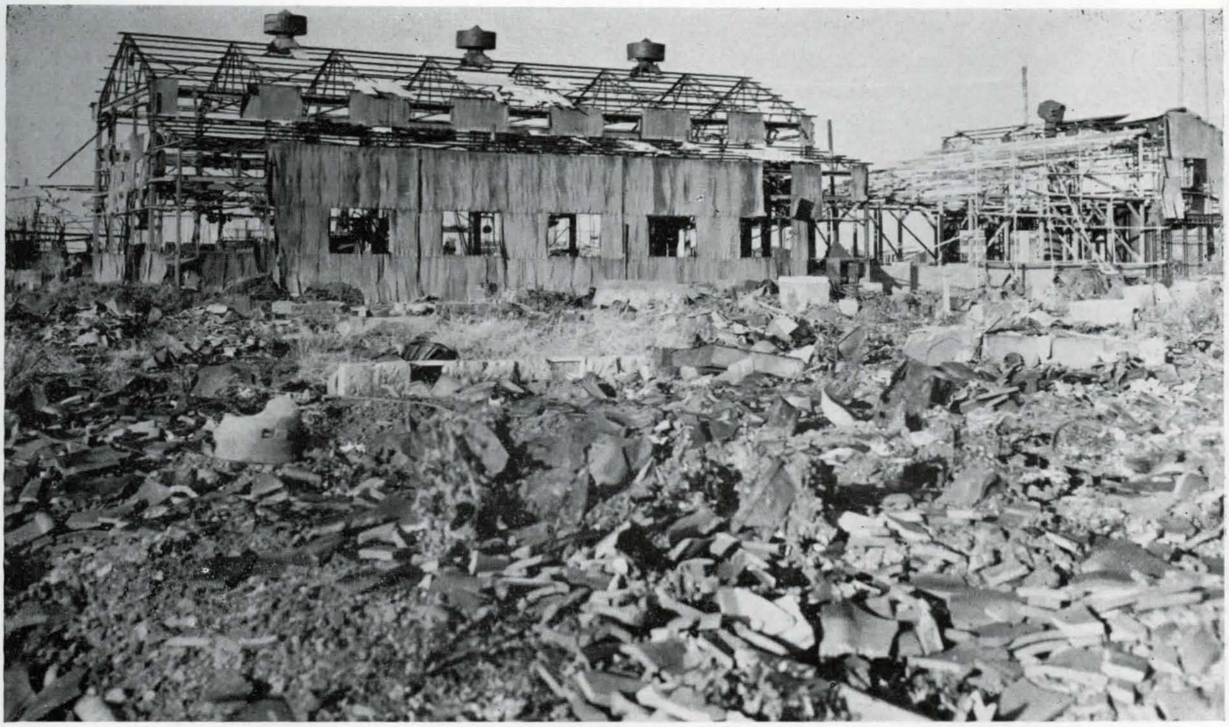


Photo 11.—One of the large home industry machine shops. Its corrugated-asbestos roof covering was cracked off by the heat, and the siding was warped, but the frame was intact. The machinery was ruined. Broken tile in the foreground was all that remained of dwellings.

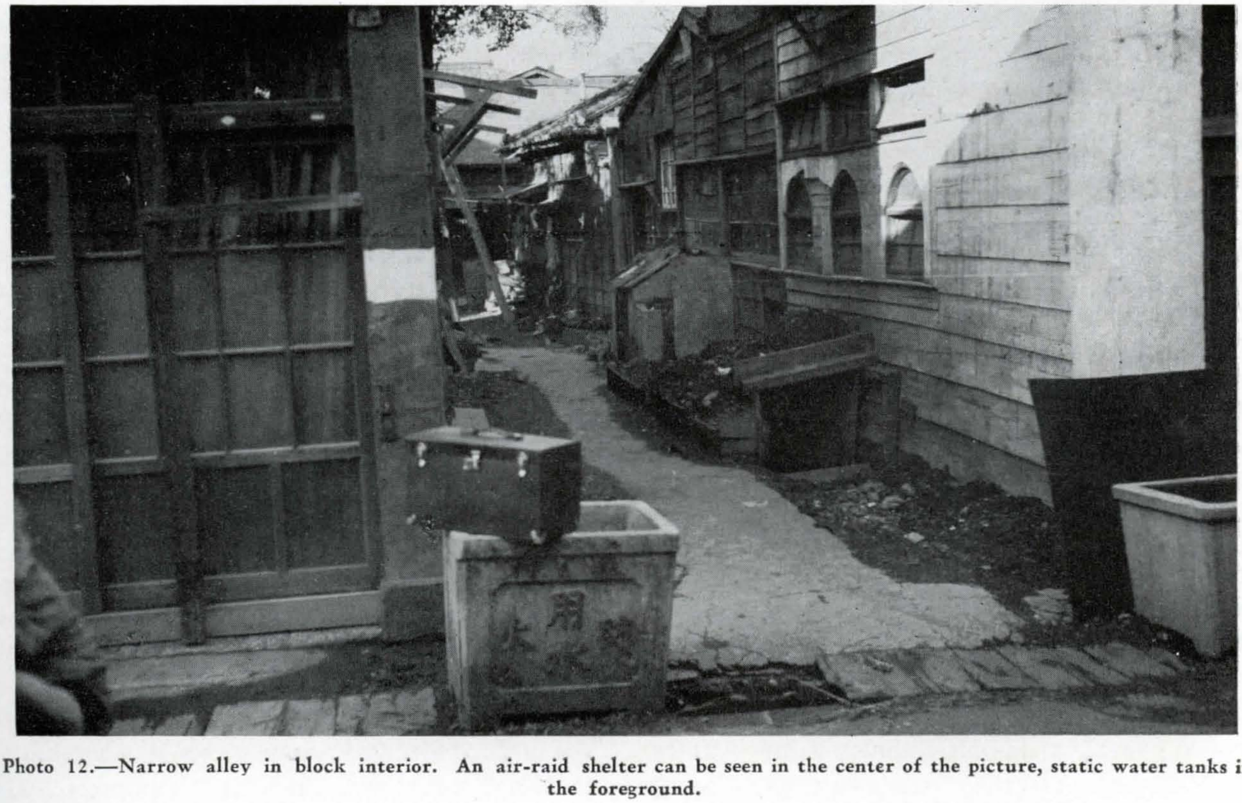


Photo 12.—Narrow alley in block interior. An air-raid shelter can be seen in the center of the picture, static water tanks in the foreground.

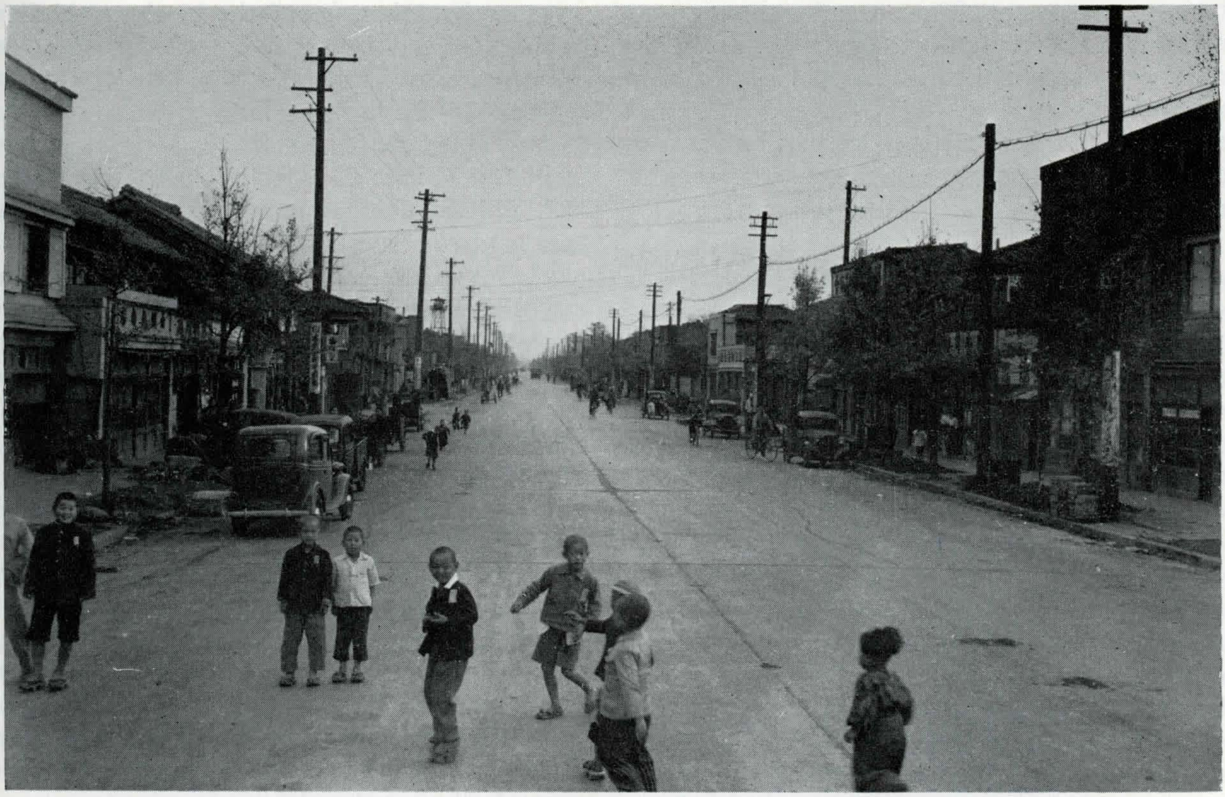


Photo 13. — This street was the widest in Zone 1 and served to divide the small blocks made by alleys into larger sections. Observe the fire tower on the left side.

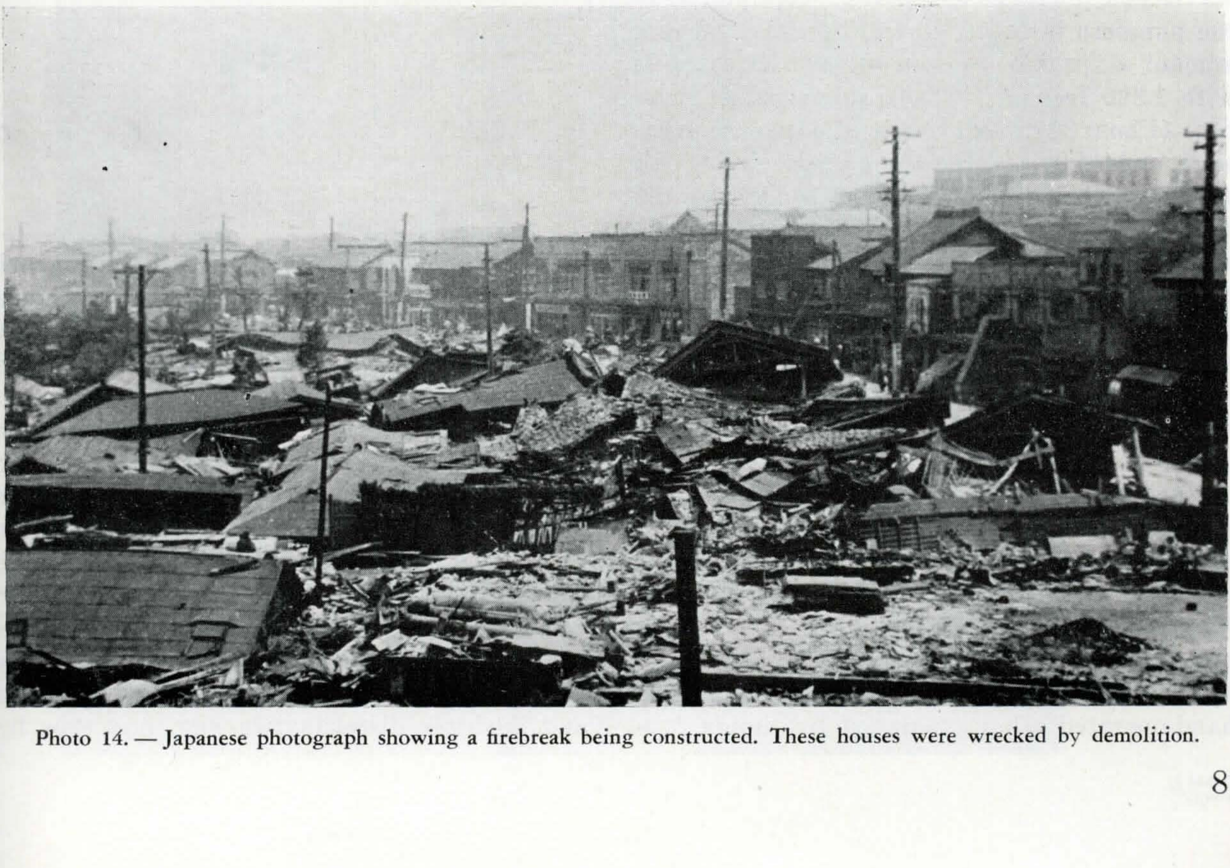


Photo 14. — Japanese photograph showing a firebreak being constructed. These houses were wrecked by demolition.

training purposes. The normal company was seven men and it was the usual practice to declare a company out of service if less than this number was present. This was a decided disadvantage during air attacks when it was a common occurrence for companies to lose one or more men during the course of an attack.

(3) Tokyo was divided into 35 Ku (wards), each of which had a main fire station and one to eleven branch stations (Photos 15 and 16). There was a total of 42 main stations and 190 branch stations in metropolitan Tokyo. The main stations housed two pumpers each and the branch stations one. These were pieces of motor-driven equipment actually manned. There was a total of 1,117 pieces of apparatus, of which 716 were standard motor-driven pumpers (Photo 17). The remaining equipment included 11 small, 500-gallon-per-minute fire boats, one undamaged ladder truck of the four originally provided (Photo 18), and hand-drawn units with 120-gallon-per-minute, motor-operated fire pumps (Photo 19). Most of the pumpers were of Japanese make with a two-stage centrifugal pump of 350- to 500-gallon-per-minute capacity, mounted on a commercial chassis (Photo 17). There were some pumpers of American make, but most of these were unserviceable due to lack of parts. Equipment on the pumpers included, in addition to a meager amount of minor equipment, two hose reels with 1,330 feet of 2½-inch single-jacket linen hose (Photo 20). All trucks of Japanese make were underpowered for the purpose for which they were used. They were not considered the equal of the equipment used in the average small American town. In normal operations the pumper answering the alarm went to the source of water supply nearest the fire, which might be a hydrant or a static tank. The hose reel was removed from the truck and a line of hose laid to the fire. The hose reel was returned to the truck and another line laid. In the meantime the truck was connected to the source of water supply. Open nozzles were used in Japan. Small stream appliances were used, reliance being placed on hand lines with ⅝- to 1-inch tips. A minimum of four trucks responded to alarms, with the ladder truck responding only to special calls. Numerous small hand-operated pumps, manned by junior firemen or householders of the block associations who had been trained in the rudiments of fire fighting, were scattered throughout the city (Photo 21). Each dwelling was also provided with a small concrete static water tank, always kept full (Photo 22), which was to be used by the individual in combatting incipient fires started by incendiary bombs.

o. Tokyo drew its water supply from lakes and streams in the near-by mountains and from wells. The average yearly rainfall in the Tokyo area was 64 inches and the streams were all permanent, so the water sources were ample. Ninety-five percent of the water was pumped by electrically-powered equipment. The reservoir capacity was approximately 80,000,000 gallons and the total daily pumping capacity was 284,000,000 gallons. The reservoir capacity servicing Zone 1 was about 8,000,000 gallons.

(1) The distribution system consisted of water mains up to 70 inches in diameter with cross feeders of 20 to 48 inches. The grid, however, was weak since it was made up principally of 3- and 4-inch pipes with about 60 percent of all pipes 4 inches or less in diameter.

Diameter of pipe having hydrants (not risers)	Percentage	Number of fire hydrants, public and private
Inches		
3	6.4	2,158
4	56.8	19,100
6	19.8	6,670
8	8.1	2,716
10	4.8	1,630
12	3.2	1,078
14	0.9	304
Total	100.0	33,656

The quantity available through such a grid system is considered inadequate for a small town; for the congested areas of Tokyo, it was hardly adequate for domestic purposes. Pressure in many districts rarely exceeded eight pounds per square inch, and the maximum pressure noted was about 25 pounds per square inch. It was reported that pressures were so low that householders sometimes permitted house connections to remain open to secure enough water for domestic purposes. There were 33,656 fire hydrants on the distribution system, of which 60 percent was on mains four inches or smaller in size. In heavy industrial and business districts two-way, post-type hy-

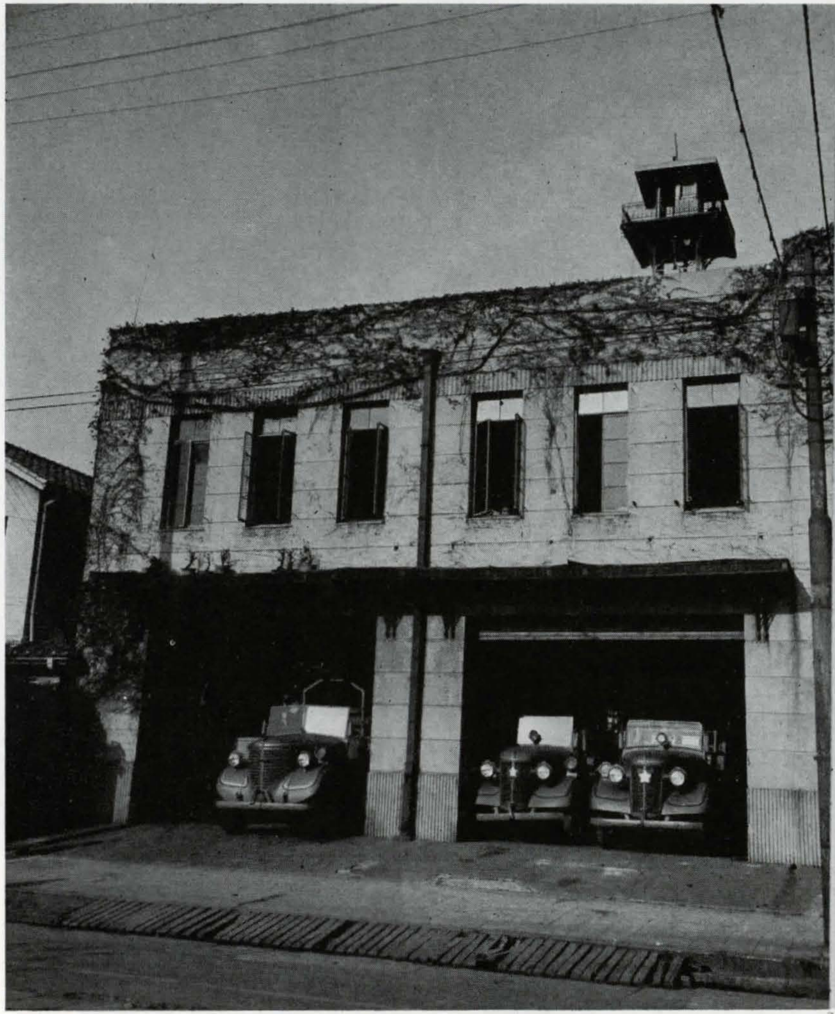


Photo 15.—A main, or ward, fire station with watch tower.

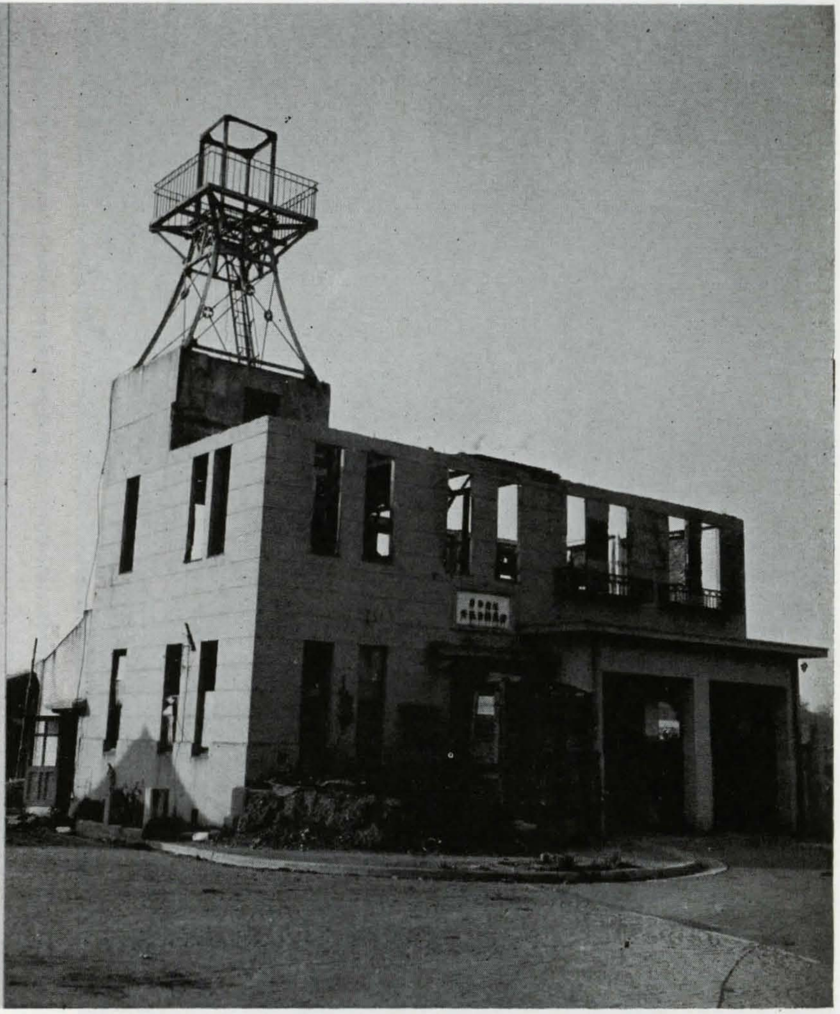


Photo 16.—A branch fire station burned in one of the attacks.

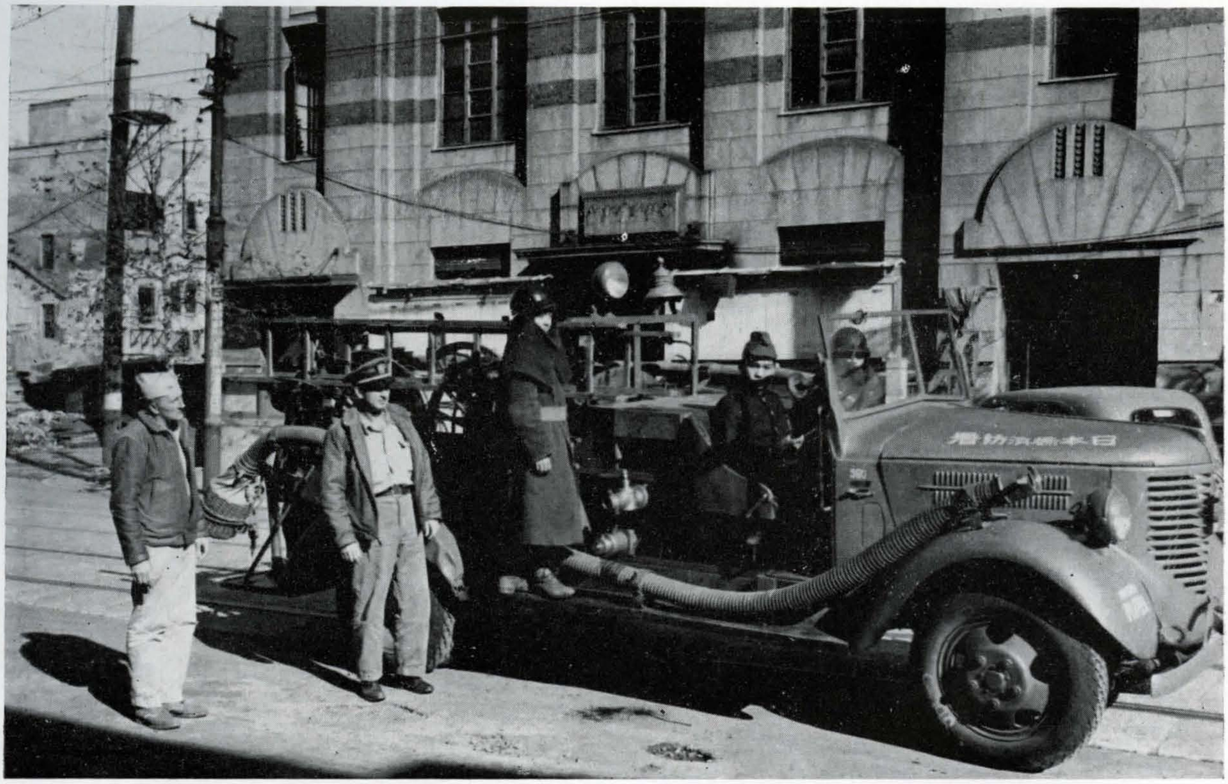


Photo 17. — Standard Japanese motor-driven 500-gallon-per-minute pumper.

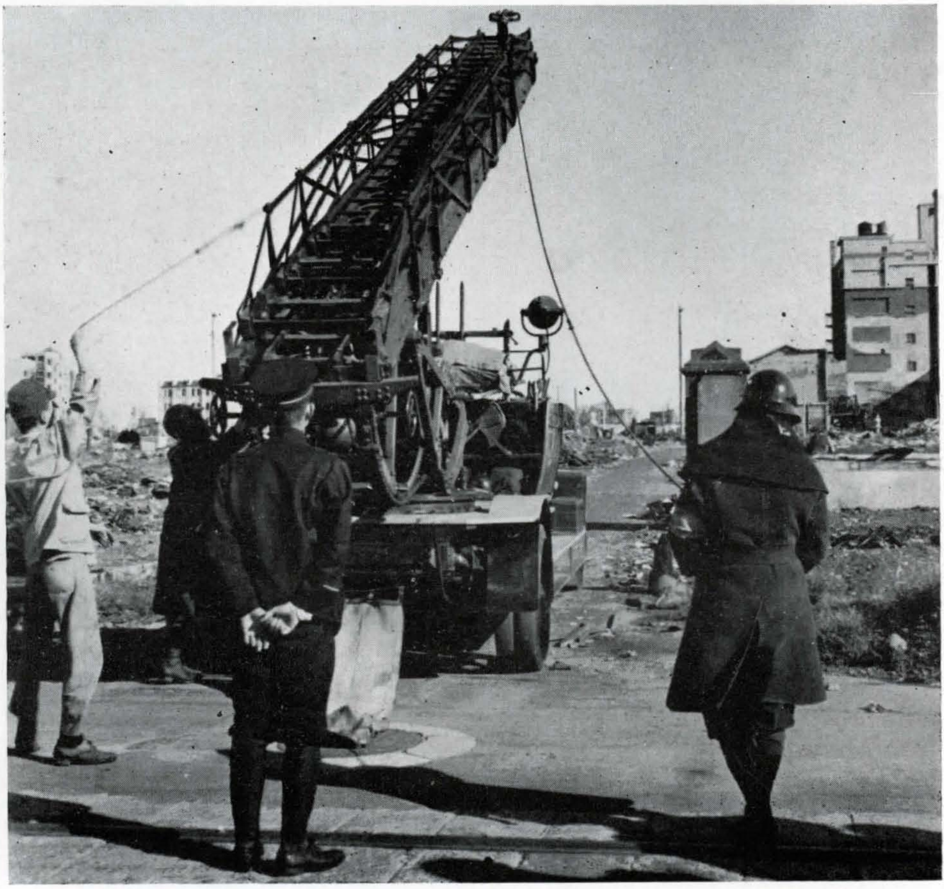


Photo 18. — One of the four aerial ladder trucks in Japan.

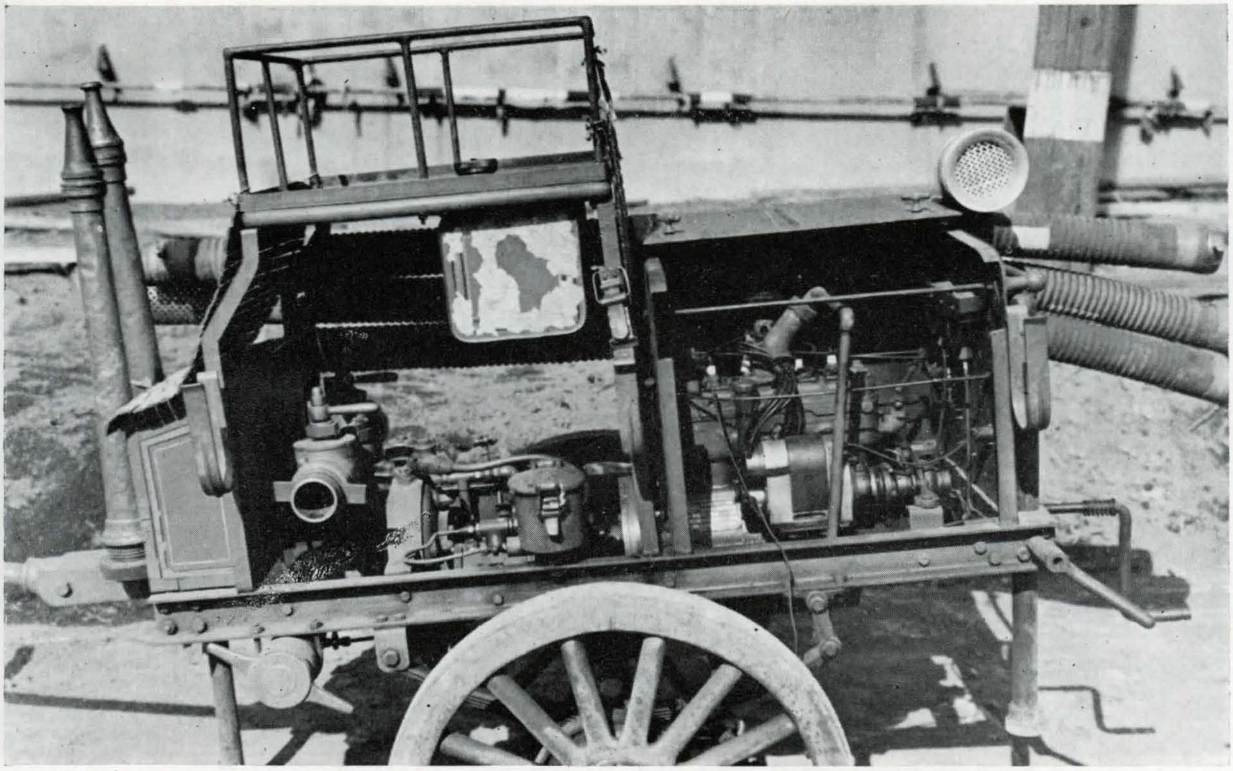


Photo 19.—Hand-drawn 120-gallon-per-minute pumper distributed throughout the city and at important manufacturing plants.

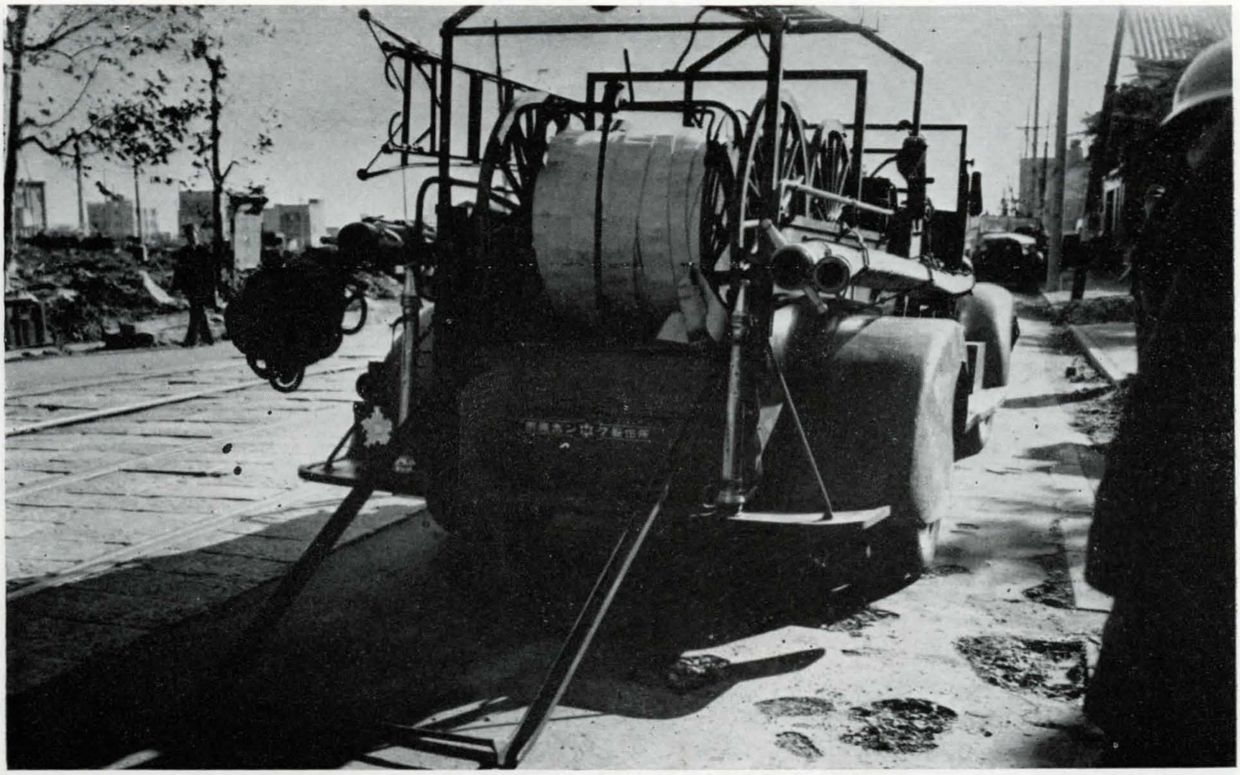


Photo 20.—Japanese-made fire truck of 300- to 500-gallon-per-minute capacity. Hose reels were removed upon arrival at scene of fire.

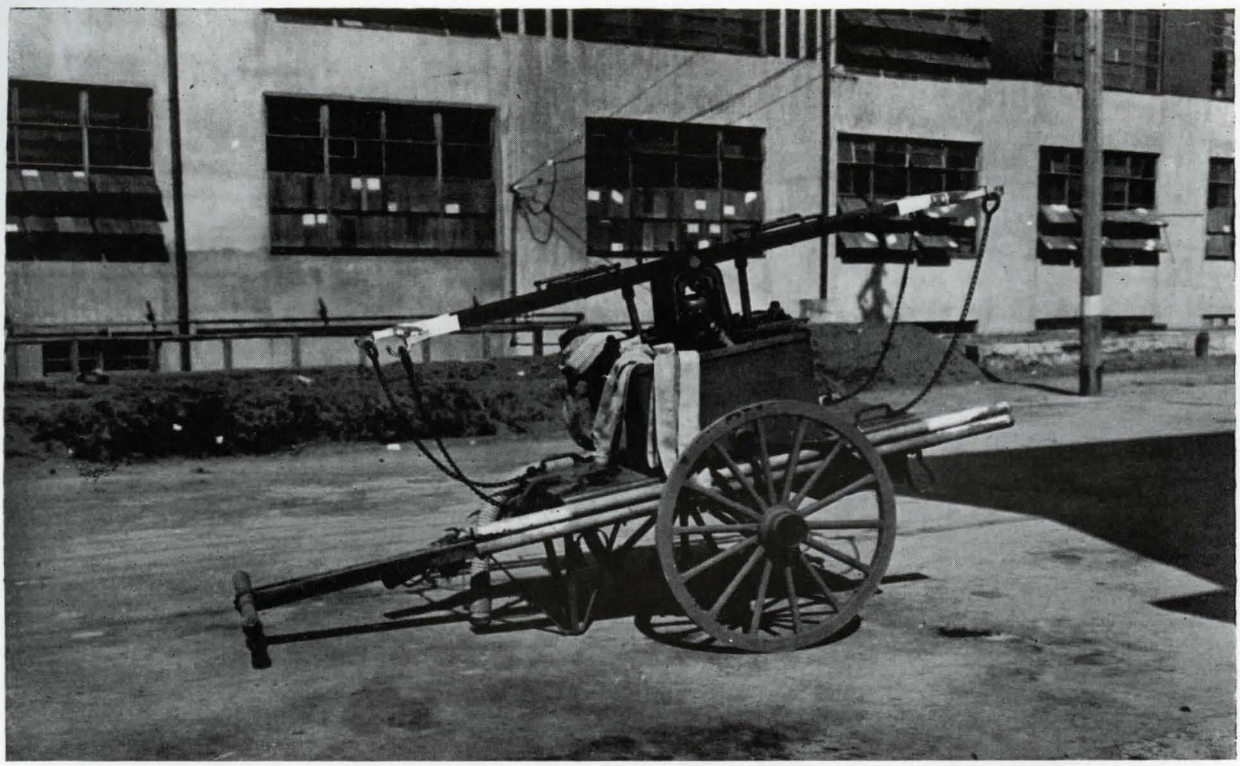


Photo 21.—Hand-drawn, hand-operated pump used by the civilian defense and in manufacturing plants.

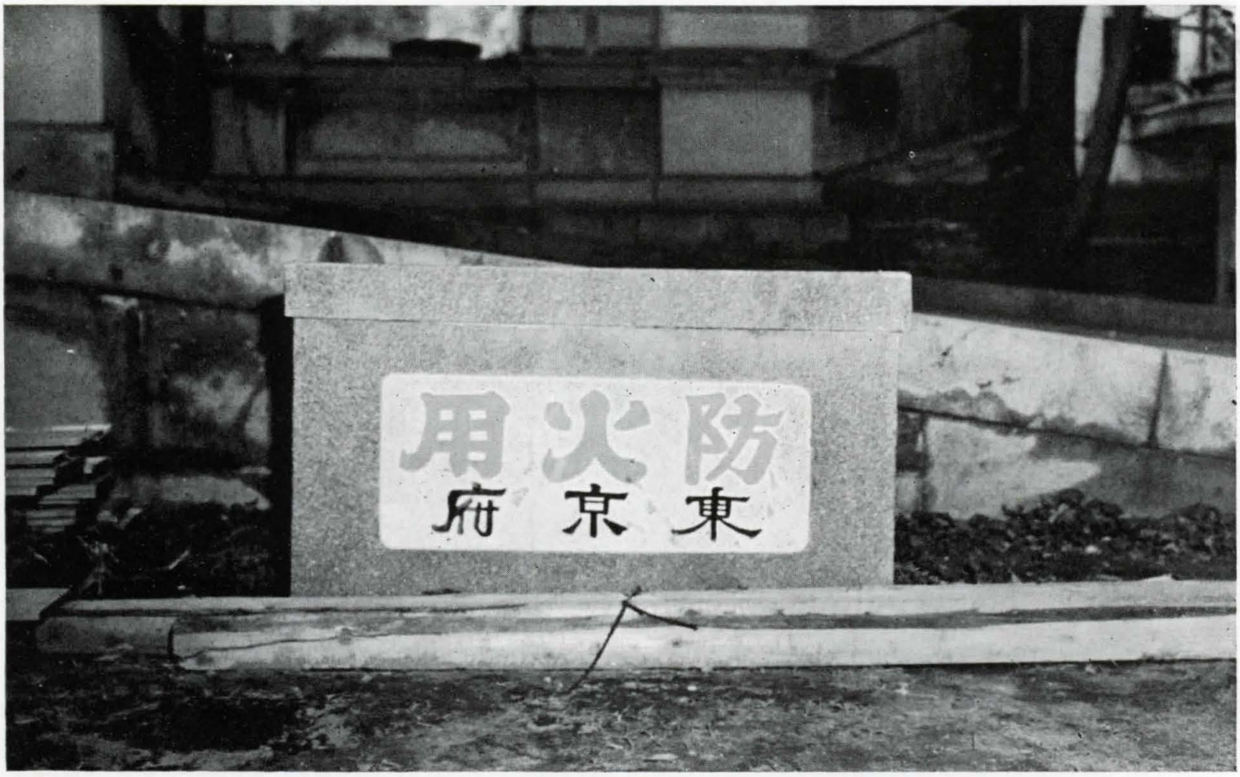


Photo 22.—Concrete static water tank with capacity of 30 to 50 gallons used by householders to combat small fires.

drants were used (Photos 23 and 24), but the great majority was one-way flush hydrants (Photo 25). Post hydrants were not equipped with pumper connections, draft being through 2½-inch hoses or from static tanks or canals.

(2) Emergency static water tanks, located throughout the city for use in case of failure of the water systems, varied in size from 20,000 to 40,000 gallons (Photo 26). Shallow wells and canals were available but no definite plan had been made for their use as indicated by the lack of platforms which would be necessary to permit fire trucks to obtain a satisfactory water supply from them. The majority of house connections were of lead and, during the 9-19 March attack, 70 percent of those in Zone 1 melted, resulting in a great drain on the water system. In the confusion caused by the attack no attempt was made to isolate these areas by sectional control valves.

p. A fairly well planned air-raid warning system was in effect, which was arranged and operated by the Japanese Eastern Army headquarters in Tokyo. Radar installations on outlying island posts and at strategic mainland coastal points, Navy picket boats equipped with radar and radio, supplemented by civilian defense and military observation posts, supplied the Army headquarters with information regarding impending attacks. At the discretion of Army headquarters telephone warnings were sent to the Metropolitan Police board and important munitions plants. The decision as to what signals should be sounded and at what time rested with the commander of the Army operations room, from which all municipal sirens in Tokyo could be operated. It was customary to withhold giving the air-raid "alert" until 30 minutes before the expected attack, and the "alarm" indicating the imminence of attack was to be given 15 minutes prior to the expected arrival of enemy planes. It is considered that the Tokyo air-raid warning system functioned efficiently, and although considerable damage was suffered by the siren system during raids, alternate methods of control which had been provided permitted the system to furnish satisfactory service.

q. Shelters for the general public were meager or lacking entirely (Photos 12, 27 and 28). Many of those in Zone 1 were built in the sidewalks and consisted of little more than shallow trenches with bamboo or light wood roofs covered with a few inches of earth. These shelters were so close to buildings that they were worthless and were not used to any great extent.

r. The fire susceptibility of Zone 1 was probably greater than that of any other similar area in the world. Fire susceptibility is a loose indication of the probability of an area burning to a specified extent or degree. All the factors discussed under "The Target" had an influence on the measure of the fire susceptibility. To give a better understanding of how some of these factors were concerned a few of them will be considered below:

(1) Assuming that an incendiary has been placed on a target, the entire target is more likely to burn, i.e., its fire susceptibility is greater, if any set of conditions exists which will tend to utilize the heat given off by the portion of the target which is burning to ignite portions not directly affected by the incendiary. The high built-upness of Zone 1 increased its fire vulnerability, since the buildings were close together or adjoining and the heat given off by those already burning ignited some of those not directly hit by bombs.

(2) A high wind was blowing during the attack, and this also temporarily increased the fire susceptibility to a very great extent, because it blew the heat and flame from the buildings already burning against those not hit by bombs, instead of allowing the heat to arise almost vertically as would have normally been the case.

(3) The vulnerability of the zone was also increased by lack of adequate water pressure for fire fighting, insufficient firebreaks, the high combustibility of the buildings and their contents, and the lack of initiative on the part of the fire department.

V. Attack Data

1. Six major attacks on the city are considered in this report. These attacks are listed in Table 1. They do not include all attacks on the city, but only the major attacks and attacks which are interesting from both the tactical point of view and from the standpoint of damage done.

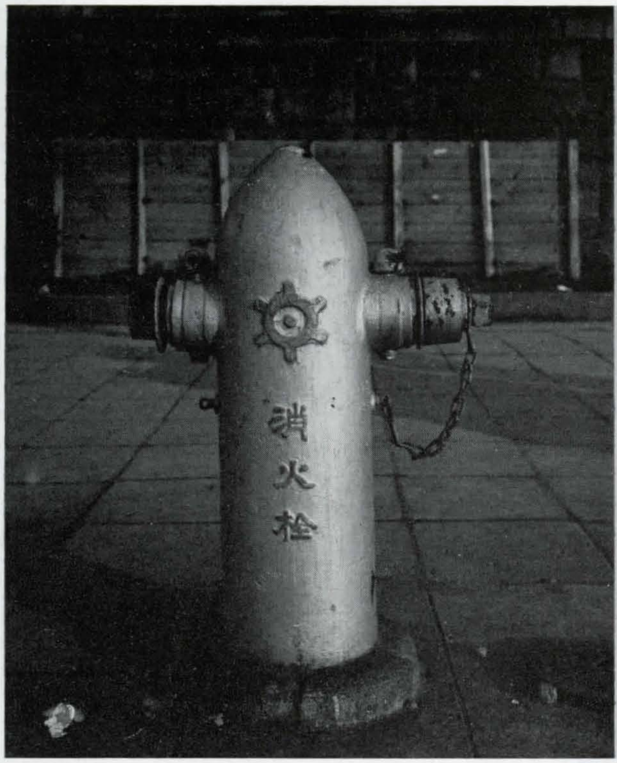


Photo 23.—Standard post-type fire hydrant. Note the valved outlets and the absence of the usual operation stem.

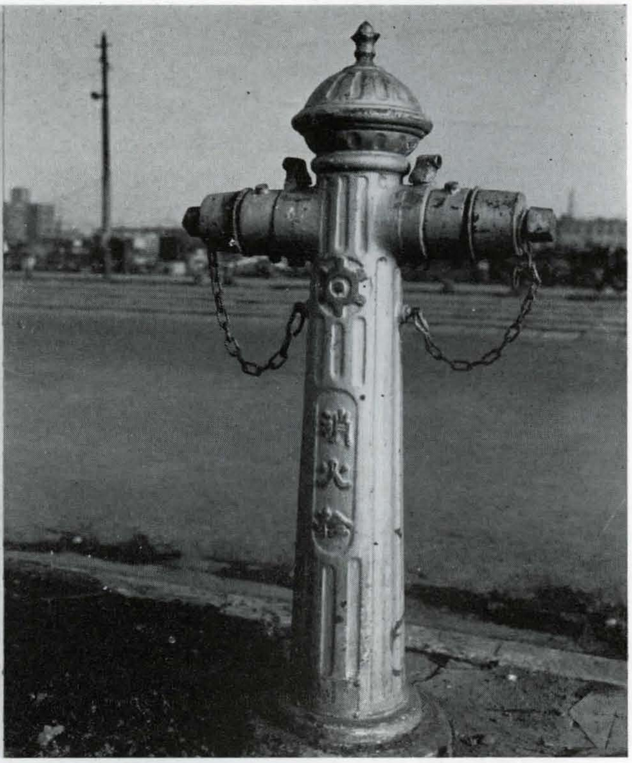


Photo 24.—Older post-type fire hydrant. None of this type had steamer connections.

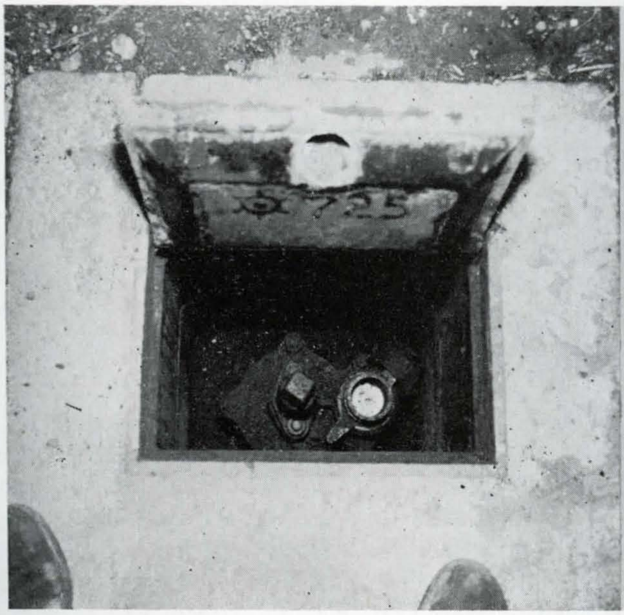


Photo 25.—One-way flush-type fire hydrant.

Photo 26.—Static water tank for emergency use. These tanks varied in size from 20,000 to 40,000 gallons.

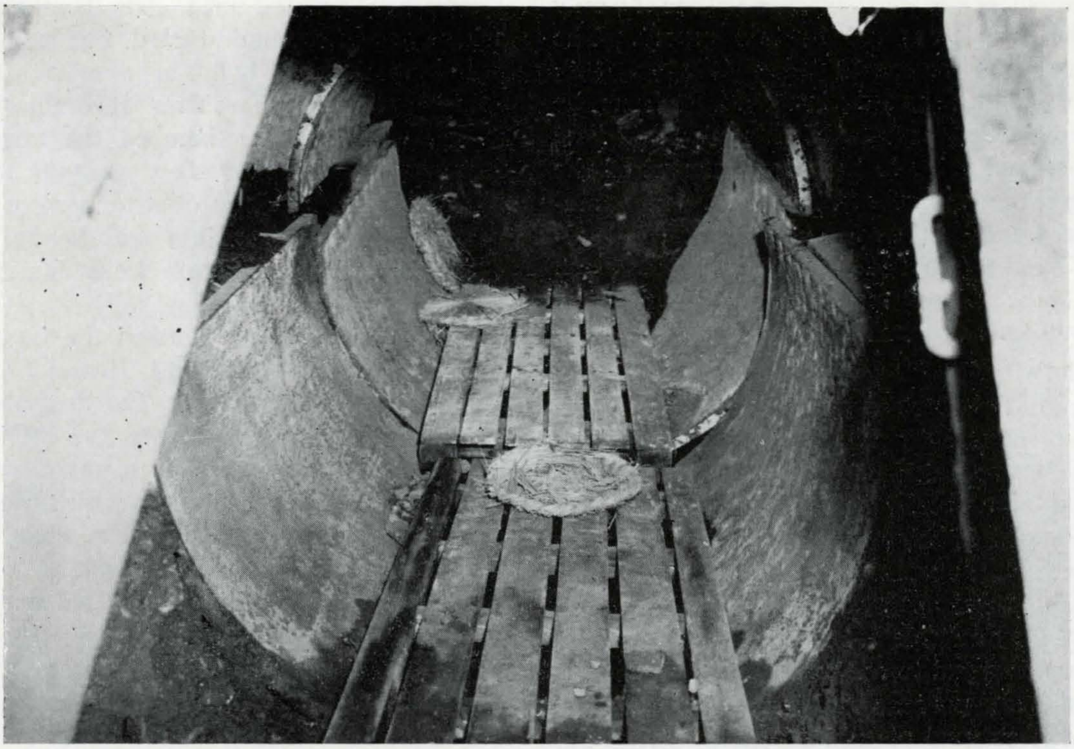


Photo 27.—Typical air-raid shelter constructed of earth-covered sewer pipe. These were usually not usable, because they filled with rain water and seepage.

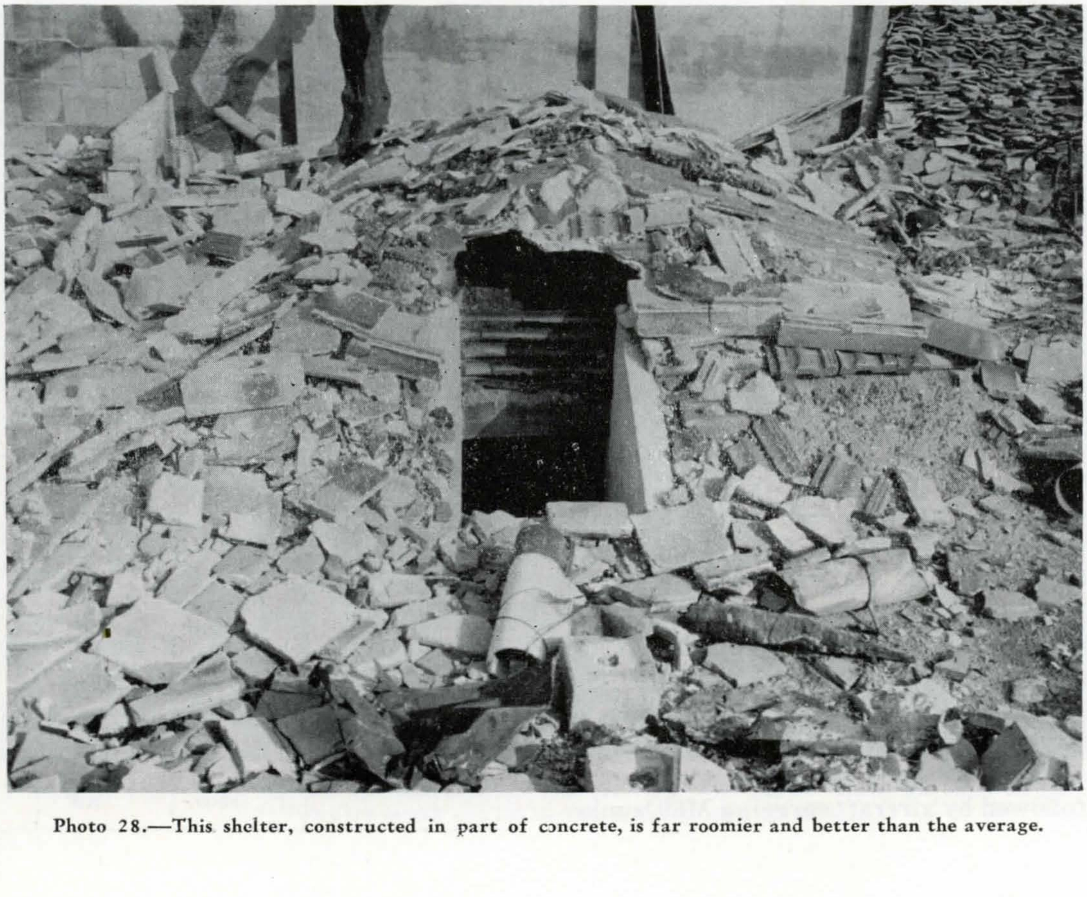


Photo 28.—This shelter, constructed in part of concrete, is far roomier and better than the average.

2. The attack of 25 February 1945 is the only daylight attack covered in this report. The bombing, however, was done through $^{10}/_{10}$ cloud cover with the aid of radar. Perhaps the most interesting feature of this attack is that it was staged prior to the abandonment of the high-level tactics in use at that time. The principal area damaged was in the east-central portion of Zone 1 (Photo 29) and amounted to one square mile. The damage was 2.2 square miles per 1,000 tons of bombs.

3. The attack on the night of 9-10 March was an incendiary attack made by the XXI Bomber Command of the Twentieth AF. This was the most effective mission ever accomplished in terms of area totally damaged per bomb tonnage dropped (Photos 30 and 31), and only one other attack, regardless of tonnage dropped, totally damaged as great an area—the attack of 25-26 May on Tokyo, in which twice the tonnage was dropped to achieve a totally damaged area only six percent greater. Prior to this attack the general plan had been to strike the strategic objective in daylight from aircraft flying in formation at altitudes of 25,000 to 30,000 feet. Mission 40 involved an almost complete reversal of these tactics. It was planned that all aircraft should make individual runs on the target at night, with the base altitudes specified at 5,000 to 7,800 feet, dropping only M47 and M69 incendiaries. The M47, a 70-pound napalm-filled bomb, was carried by the pathfinder squadron of each of the three wings flying the mission to serve the dual purpose of starting immediate "appliance" fires (i.e., fires of such magnitude as to require the attention of motorized fire-fighting appliances) and of effectively marking each aiming point (Figure 1). Maximum loads of 184 M47 bombs per aircraft were carried, with the bombs clustered six to a 500-pound station with T19 cluster adapters. All other aircraft carried M69's (6-pound incendiaries) in delay-opening clusters capable of being aimed, and set to function at 2,000 to 2,500 feet. Both E28 incendiary clusters (one nose fuze) and E46 incendiary clusters (two tail fuzes) were used. Intervalometer settings were 50 feet for clusters and 100 feet for the M47 bombs. The general plan of attack called for pathfinder aircraft to strike the aiming points, followed by aircraft carrying M69 bombs. Crews were briefed not to drop bombs on areas where good fires had started, but to make visual correction and bomb areas within the general target zone where fires were not observed.

a. The 73rd Wing bombed the target area from 6,620 to 8,950 feet through 2/10 to 10/10 overcast. Axes of attack were 290° to 309°. Flak was medium and heavy, intense and accurate; 23 aircraft were damaged and one was lost.

b. The 313th Wing bombed the target from 5,850 to 8,000 feet through 1/10 and 2/10 cover. Axis of attack was 305°. The first planes encountered generally accurate fire of moderate intensity, but succeeding elements received lighter and less accurate fire which diminished in strength until the last units received no fire; nine planes suffered minor damage.

c. The 314th Wing bombed the target from 4,900 to 9,200 feet through 2/10 overcast. Axes of attack were 210° to 240°. Flak encountered was medium and heavy, accurate to inaccurate; 10 aircraft were damaged and eight were lost.

d. Numerous empty M69 cases were found throughout the area. An attempt was made to determine the percentage of duds. Only one M69 was found that had not functioned and no evidence was found of clusters having failed to open. No M47's were found. The fact that no duds of any consequence were found does not necessarily indicate perfect functioning since malfunctioned bombs will detonate in a fire.

e. Weather just preceding the attack was fair with a moderate wind from the southwest. There had been no rain or snow for several days preceding the attack. The following table of wind velocities for the night of 9-10 March was obtained from the Japanese Weather Bureau located about two miles from the area affected by fire. Although this information was not se-

Wind Velocities — 9-10 March 1945

	Time	Direction	Velocity
			MPH
9 March 1945	2200	SW.	13
	2400	W.	09
10 March 1945	0200	NNW.	21
	0300	NW.	28
	0500	NNW.	20
	0700	NNW.	10
	0900	NW.	14

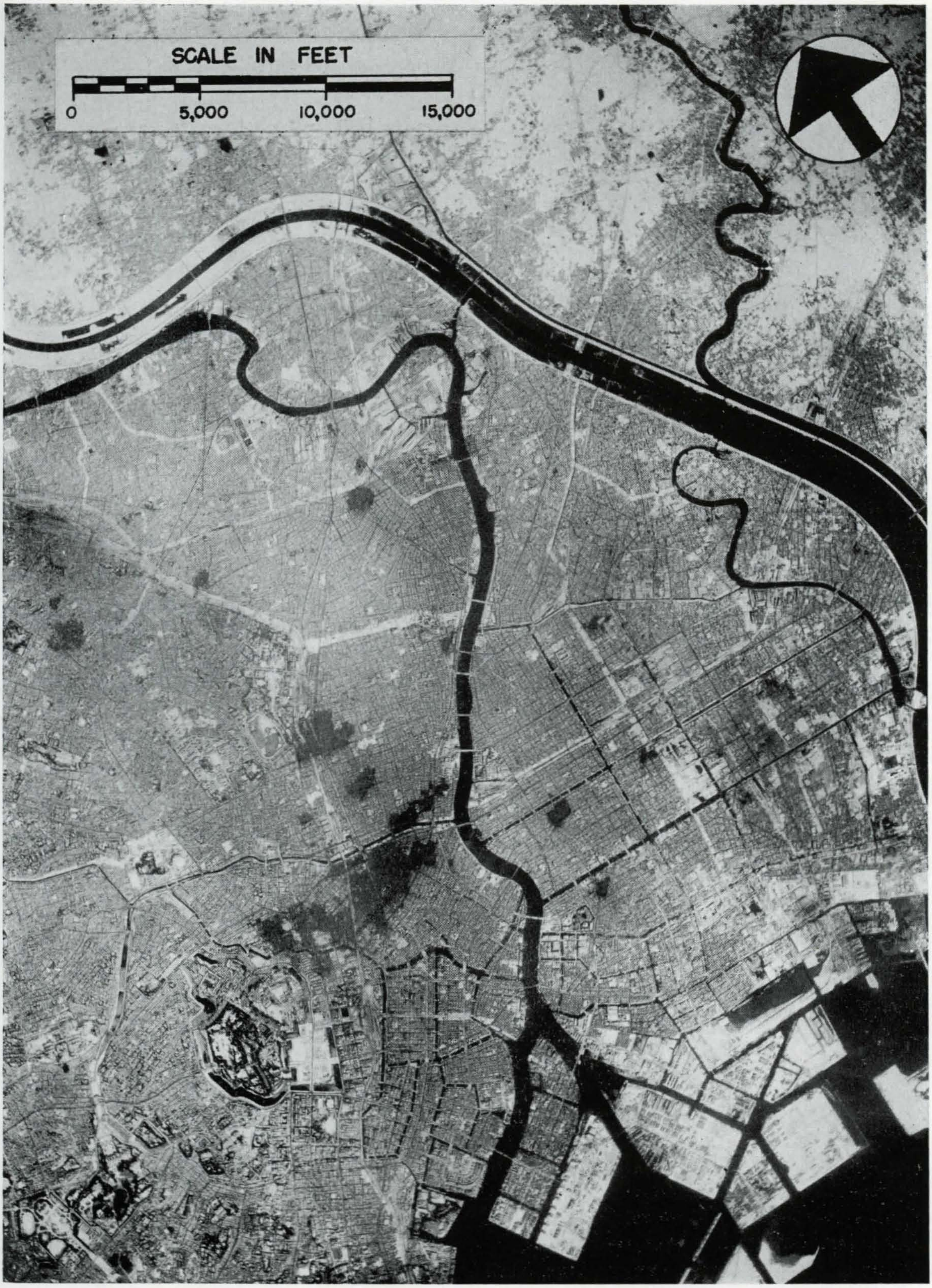


Photo 29.—Aerial photo taken between the attacks of 25 February and 9-10 March. There was snow at the time of the 25 February attack and the burned out areas show up as black.

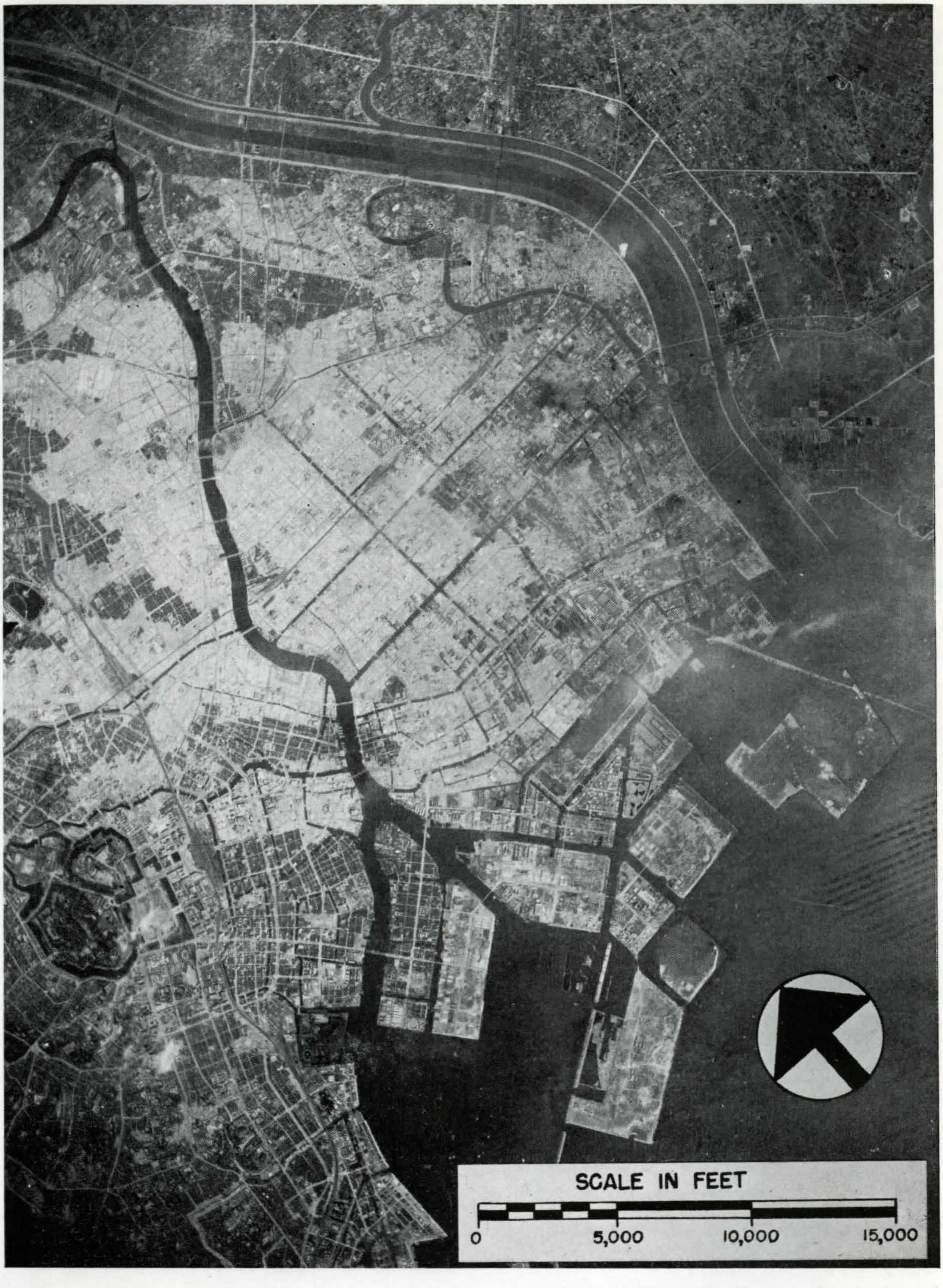


Photo 30.—Aerial photo taken 11 March showing damage from the attack of 9-10 March. In this photo the snow has melted and the burned areas show as light gray.

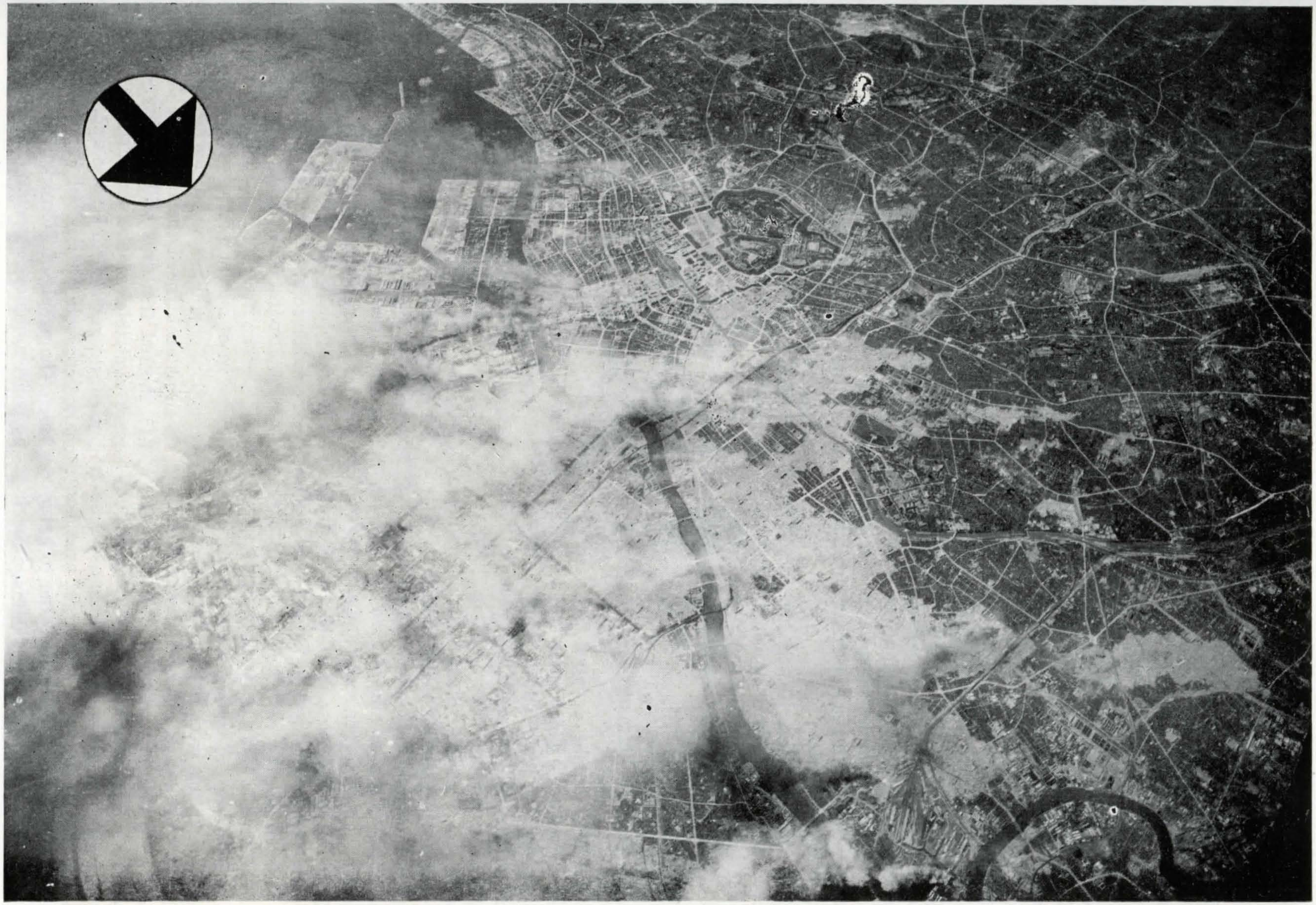


Photo 31.—Oblique photo taken 10 March showing most of the damaged area and some of the fires still burning from the attack of 9-10 March.

cured in the fire zone, it serves to indicate the trend of wind conditions. As can be seen from the tabulations, the wind increased in velocity just prior to the attack and continued to increase until a maximum of 28 miles per hour was reached at 0300 hours, at which time all planes had left the target area. Plant managers and residents interviewed in the burned area estimated wind velocities just prior to the attack at about 17 to 25 miles per hour with a maximum during the conflagration of 55 to 70 miles per hour. It was described, without exception, as being "too strong for a man to stand up to." The chief of the fire department estimated the velocity at 50 miles per hour during the height of the fire. It is possible that much higher velocities were attained at the perimeter since the gas rising above the area drew in vast quantities of air. This is a common occurrence during conflagrations.

4. The four remaining attacks listed in Table 1 were carried out with approximately the same tactics as used on Mission 40, with results varying from excellent to poor as shown in the table.

VI. Analysis of Damage

1. The M47 bombs dropped by pathfinder planes started fires which were spread rapidly by the high wind. Bombs from following planes started additional fires which later merged to form one vast mass of flame as viewed from the air. Planes which bombed during the latter part of the attack found visibility very poor and dropped bombs short of the target area. These bombs started fires in the congested industrial area south and east of Zone 1. (About 0.8 square mile of the total 11.08 square miles comprising the Zone 1 area had been burned in the attack of 25 February 1945.) The 9-10 March attack burned all of Zone 1 area east of and a major portion of Zone 1 area lying west of the Sumida River. Small areas in the extreme northwest tip and a narrow strip running northwest in the southwestern corner escaped damage (Photos 30 and 31, Figure 3). Few bombs hit these areas because the last planes over the target area had difficulty locating aiming points due to extensive fire and smoke. The total damage resulting from this single attack was 15.8 square miles of the heart of the city. Calculations indicate that about two-thirds of Zone 1 was burned along with about nine square miles of the great industrial area bordering Zone 1. Figures furnished by the Metropolitan Police Bureau show 267,171 buildings burned in this one attack. The Japan Year Book of 1944 stated that Tokyo had 1,057,921 buildings in 1938 of which 692,731 were dwellings. Based on these figures the attack of 9-10 March totally damaged about 25 percent of all buildings in Tokyo.

2. The 28-mile-per-hour wind during the course of the attack which increased in velocity as the fires merged, contributed considerably to the intensity and further spread of the conflagration. The direction of the wind, north-northwest and northwest, caused the fire to spread to the highly congested tenement and industrial district east and south of Zone 1, resulting in considerable damage to industrial plants. Fire to the south and southeast burned itself out against open areas, the Diversion Canal or firebreaks. The fire west of the Sumida River burned itself out either against areas burned in the 25 February 1945 attack, or against the river. Isolated fires to the southwest and northwest caused by spill-overs were relatively small and were controlled by fire department operation and open areas.

3. The highly combustible nature of the city resulted in an intense fire of short duration. Observers stated that the heat was so intense that entire block fronts burst into flames before the main body of the fire reached them. The heat intensity was indicated by the absence of smudges on concrete buildings. Combustible contents of buildings burned completely, leaving no evidence of what the contents may have been, and without marking the walls with smoke. The fire chief stated that the fire had burned itself out by morning except for fires in industrial buildings. An aerial photograph taken at about noon the following day (Photo 31) showed few fires still burning. No data were available on the temperatures reached, but considerable melted glass and, in one case, melted concrete were noted (Photos 32, 33 and 34). The people of Tokyo had been instructed by police and block associations in the handling

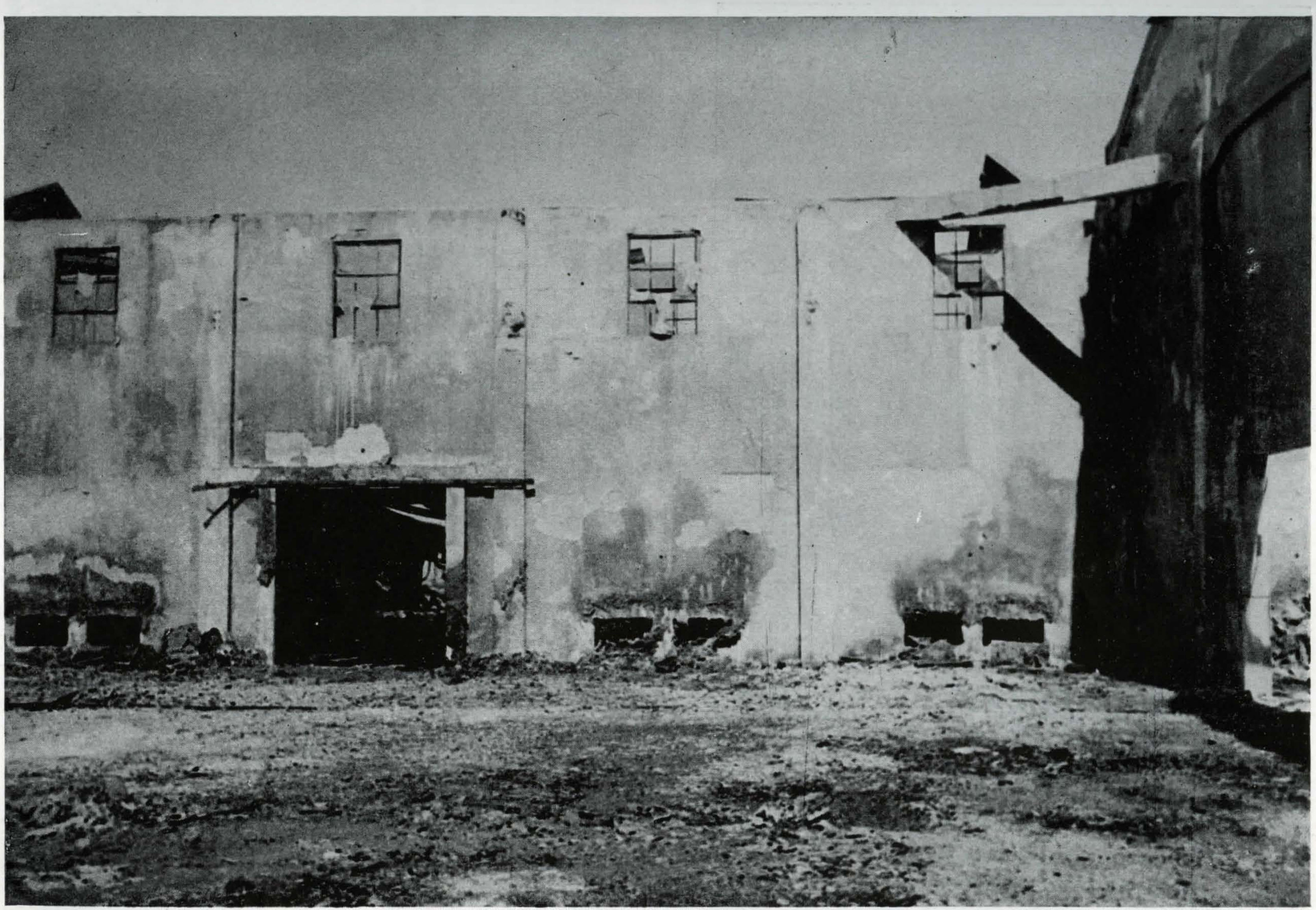


Photo 32. — Interior of burned warehouse built with reinforced-concrete walls and unprotected steel roof. (The collapsed roof members had been removed.) Note melted glass windows and the melted concrete at the lower windows. See Photos 34 and 35 for close-up views.

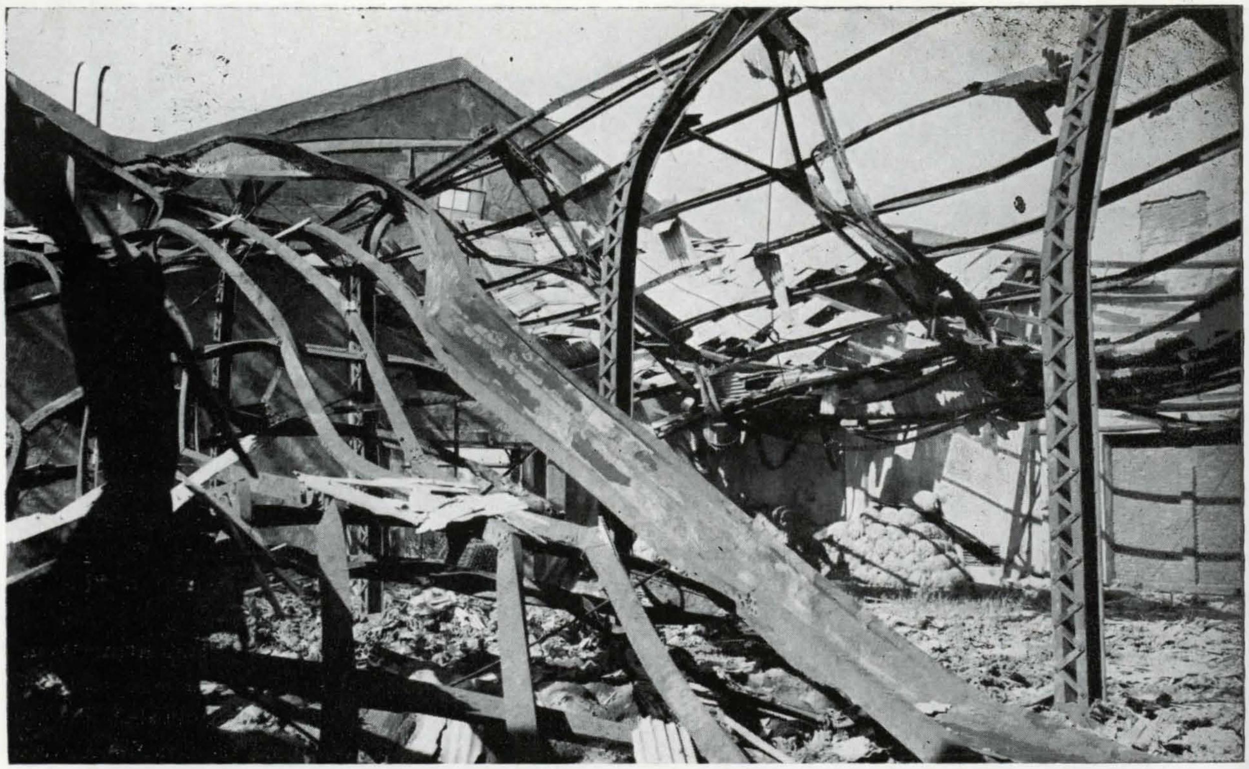


Photo 33. — Twisted steel roof members in other end of warehouse shown in Photo 35. These are still in place. Contents were wooden cases and rice straw.

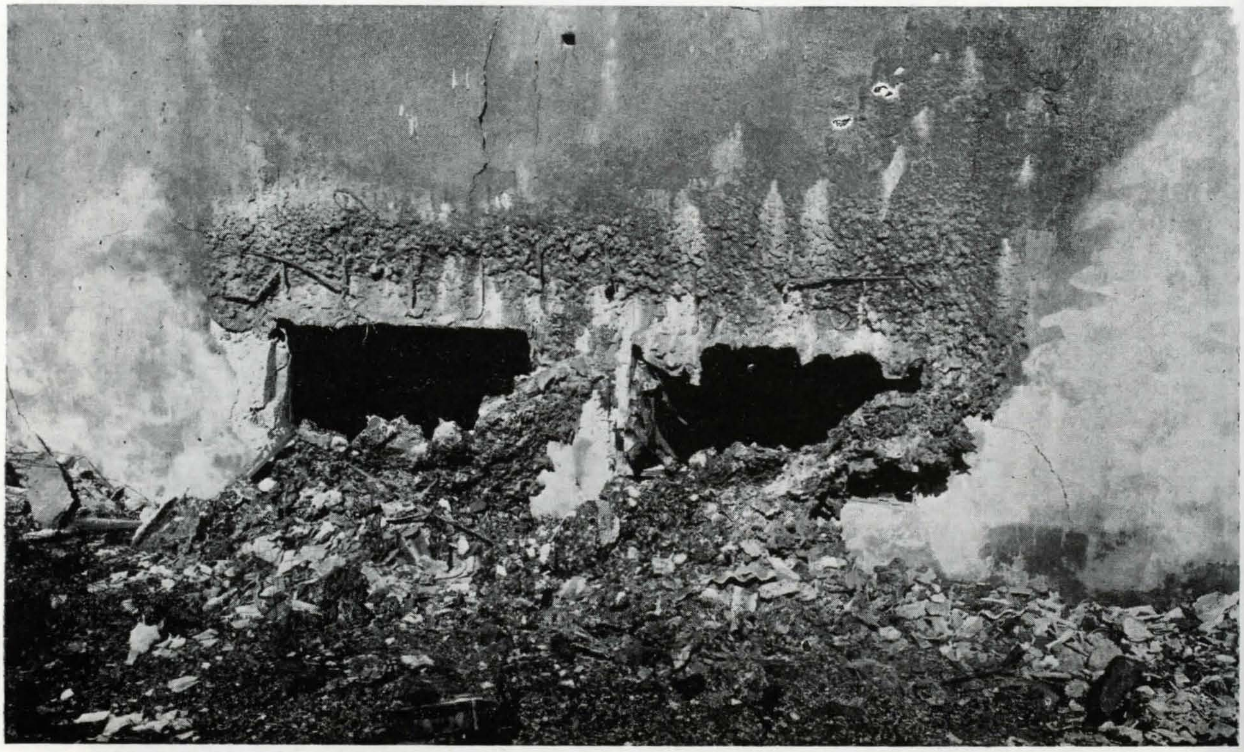


Photo 34. — Close-up view of melted concrete and reinforcing bars shown in Photo 33. These windows were located near the floor level. The exterior of the wall showed no fire marks.

of bombs and the extinguishing of incipient fires. The military authorities, however, had advised that all attacks would be made at high altitude and that the attackers would be sufficiently dispersed to offset the possibility of any great area fires. This attack was made at a low altitude by a much larger number of planes than had been expected, taking both the military and the general public by complete surprise. At the beginning of the attack, the people attempted to extinguish the fires started by the first planes, but, as the attack continued, they realized that such action was hopeless and confined their efforts to saving personal belongings and to escaping. Plant employees attempted to combat fires started in industrial buildings and, by virtue of better training and equipment, they were able to confine the fires in some cases. When bomb concentrations were heavy and combustible contents were present, however, their best efforts were futile. The inhabitants, in general, fled to parks, canals, and rivers, or left the area entirely if possible. Fire lanes were used as corridors and, as such, were the means of saving many lives.

4. The Tokyo fire department organization was not prepared to combat fires of any magnitude, for too much dependence was placed on the individual stations to respond to a fire without notification from the central headquarters. This was satisfactory for ordinary fires, since by this method it was possible to extinguish quickly incipient fires in highly combustible areas. The general plan for air-raid protection included the use of apparatus outside the area under attack to attempt to confine the fire and prevent it from spreading. This was more or less standard fire department practice in any conflagration but its proper execution depended on many factors, such as ample equipment and men, adequate water supply, and favorable weather conditions. The conditions during the attack could hardly have been more favorable for a conflagration, or more unfavorable from a fire-protection standpoint. Tokyo fire department equipment and personnel were inadequate, as was the water supply. These shortcomings, coupled with a high wind and highly congested, combustible buildings, resulted in the many small fires growing into a conflagration in a matter of minutes. The chief of the fire department stated that the situation was completely out of control 30 minutes after the first bomb dropped and efforts to combat the fire were futile. Attempts were made to hold isolated fires in check. A total of 186 fire trucks was destroyed in all attacks on Tokyo, 95 of which were lost in this attack. This figure does not include small hand trucks of the type used by civilian-defense organizations. Most of the damaged fire trucks were dispatched from outside the fire zone to combat the fire and were subsequently trapped and burned. Five of the 15 large fire stations were completely gutted. One station was noted where firemen were killed and equipment burned in the station. This equipment was still in its original position even though the attack occurred 8 months prior to the investigation.

5. The highly combustible residential structures burned quickly. An inspection revealed that not a single dwelling remained in the burned area. All combustible material was completely consumed. No charred remains of combustible structural members of residences were found. The area was simply a mass of shattered tile, concrete static water tanks, and twisted steel (Photos 35 and 36.)

6. Industrial plants of fire-resistive construction were few in the fire-damaged area. Three plants were inspected in which some of the structures were of this type. In only one was there any evidence of bombs entering the building and starting fires. The manager of this plant claimed that the bombs falling at an angle entered through the windows, which is unusual for a bomb of the M69 type. No building was sufficiently near, however, to cause damage from exposure fires and it is therefore assumed that this statement was correct. The entire structure, a reinforced-concrete warehouse 25 feet in height, was structurally damaged (Photos 37, 38, 39). The other two plants suffered damage from exposure fires. One, a cable plant, was completely gutted, while the other, a fuze plant, suffered slight damage to the building and total damage to the contents. Noncombustible structures predominated in the industrial plants studied which were, for the most part, machine shops, steel works,

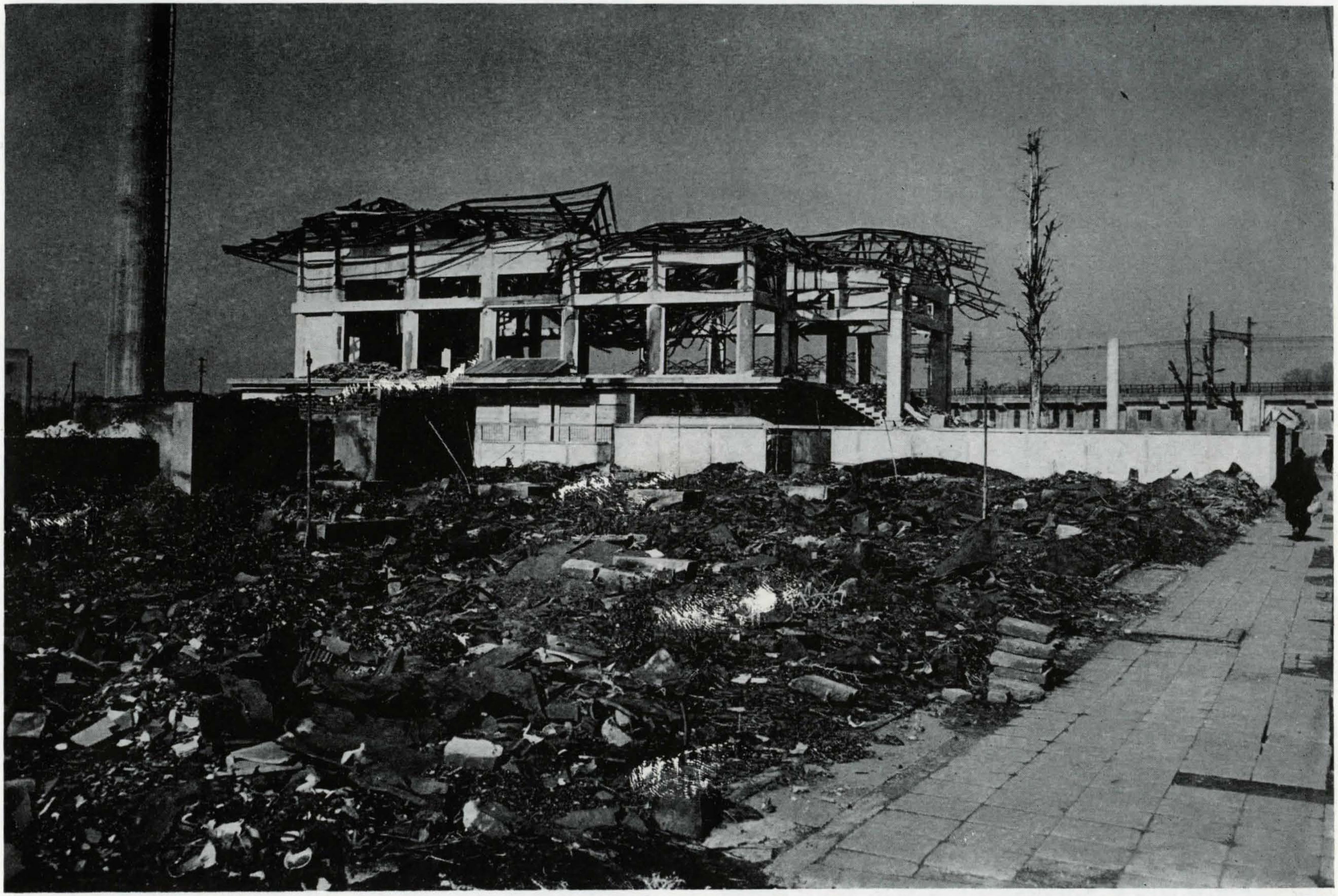


Photo 35.—The foreground of this picture shows a typical burned area. Japanese homes formerly stood on this site, but all that remained was shattered tile and some twisted metal roof covering. The station in the background burned and the steel roof supports were warped beyond use.

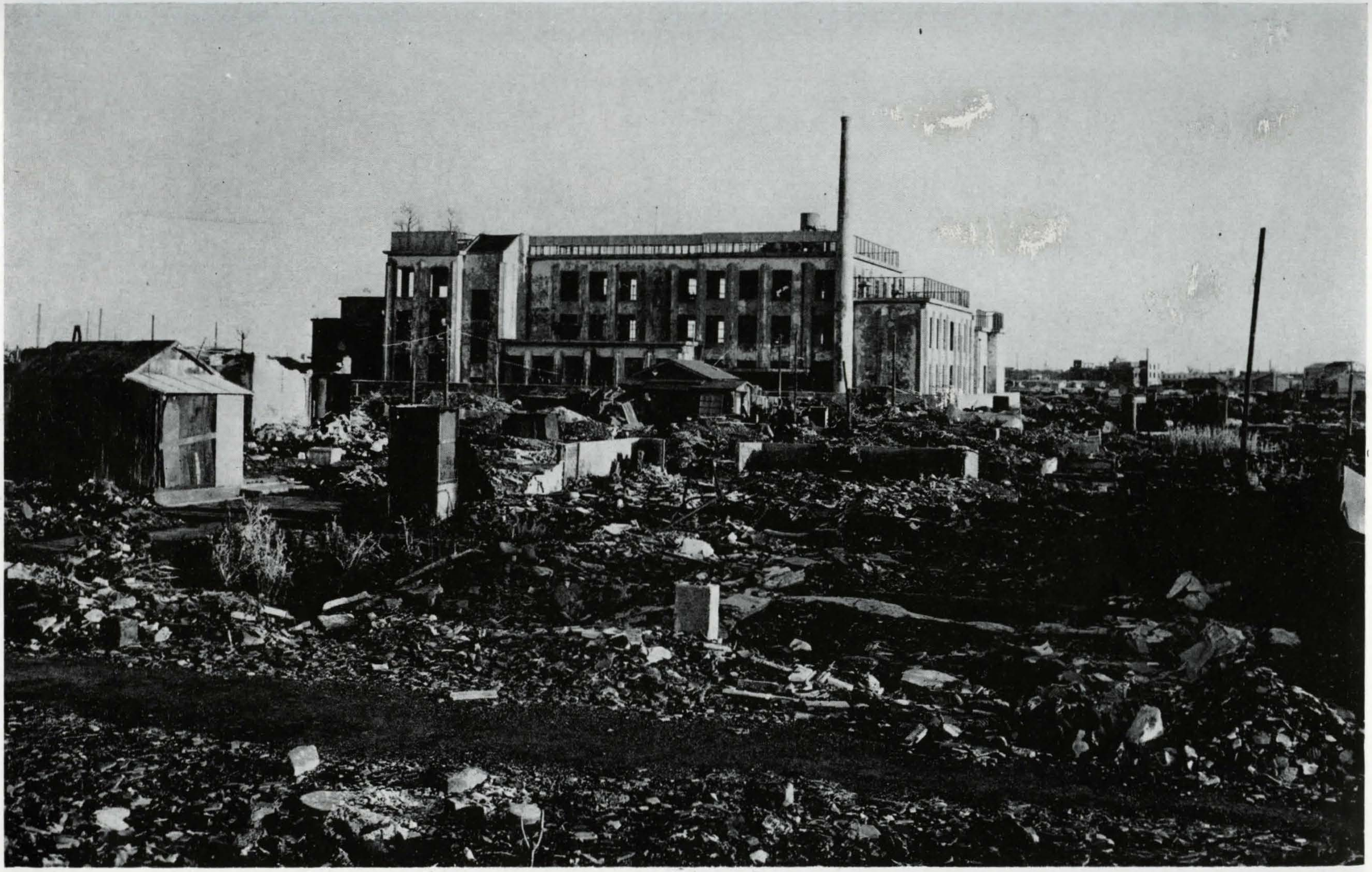


Photo 36.—Shattered tile from the roofs, the building foundations and small static tanks are about all that remain after the burning of typical Japanese buildings which stood here before the attack of 9-10 March. The fire-resistive building in the background burned from an exposure fire.

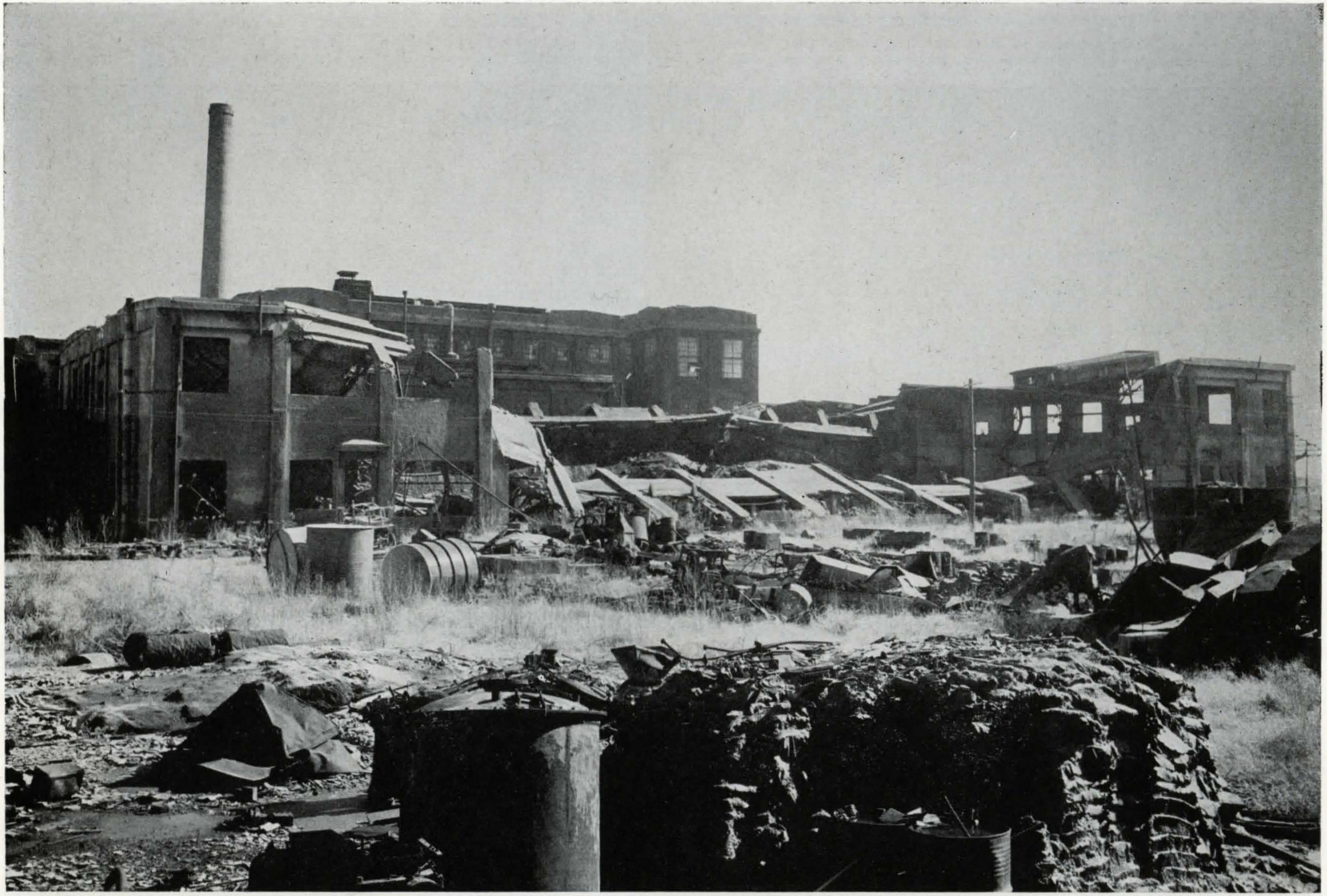


Photo 37.—General view of damaged concrete warehouse with unprotected steel roof trusses. Japanese stated that the bombs entered through the windows.

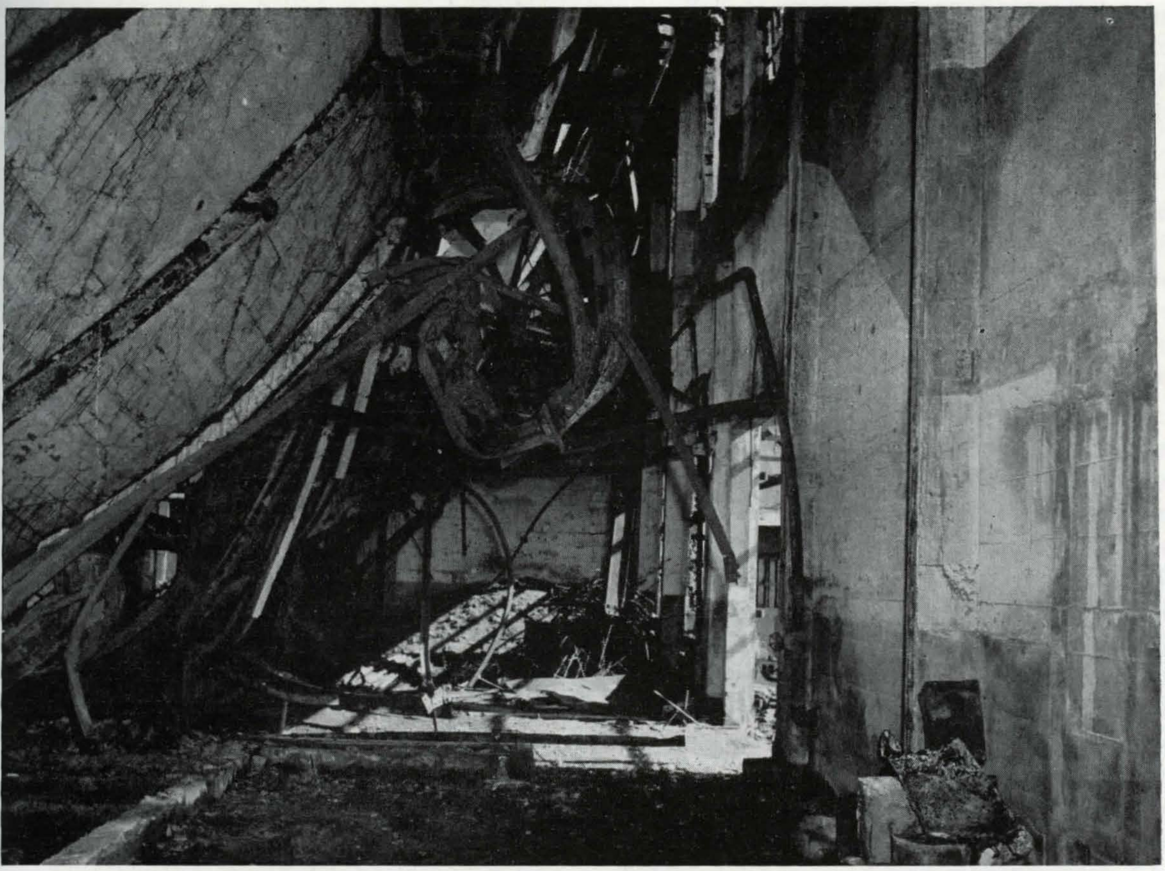


Photo 38.—Interior of the warehouse in Photo 37 showing sag of roof supports and collapse of roof. Roof was 5-inch concrete.

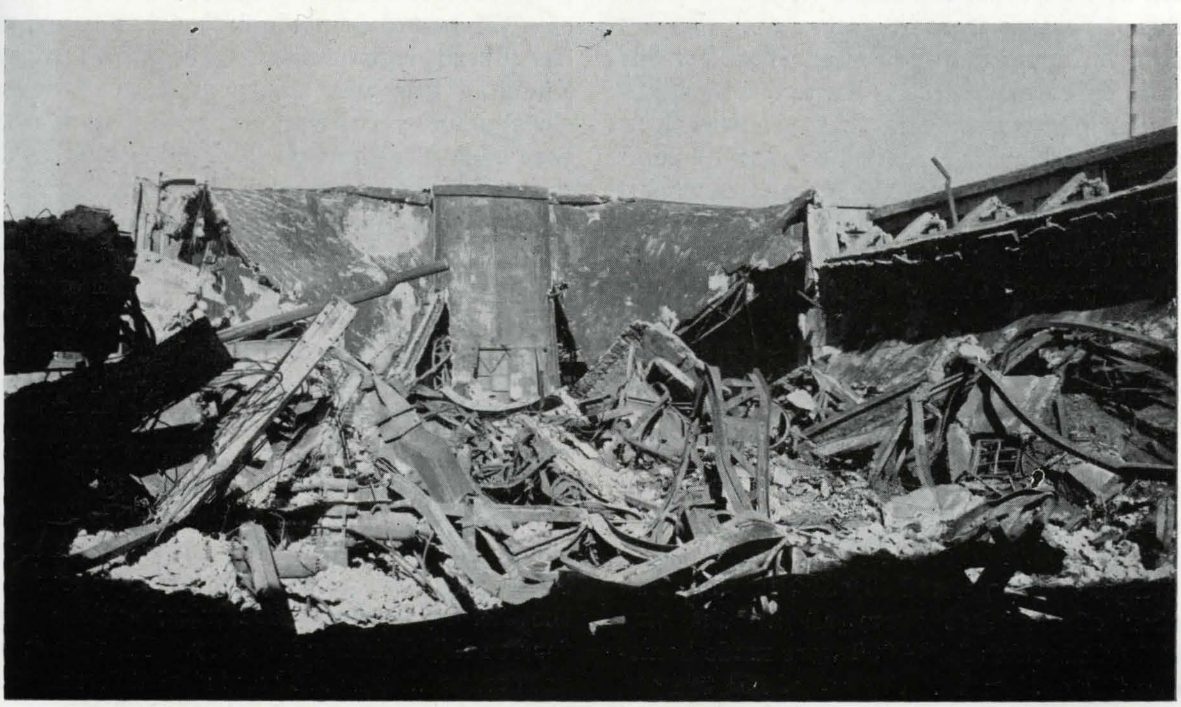


Photo 39.—View from one end of the warehouse shown in Photo 37 showing the collapsed roof and a collapsed wall.

foundries, and textile mills. Bombs readily penetrated the corrugated-asbestos-cement or corrugated-iron roofs. When sufficient combustible contents were present, the structure was almost always totally damaged, and all that remained was a mass of sagging steel members and shattered roof covering. This condition of total damage also existed in many instances where buildings were adjacent to near-by dwellings, as were the numerous small shops scattered throughout the area (Photos 40, 41, and 42).

8. No over-all figures for production loss were available since not all plants in the area were visited. However, an estimate of the loss of production to the damaged area resulting from the 9-10 March attack was made by the local managers of 10 of the larger plants. Building and equipment damage in these 10 plants ranged from five to 100 percent and loss in production was estimated at 50 percent. It is believed that 50 percent is somewhat low since home industries which accounted for much of the production capacity of the area and which were totally damaged were not included. The population of Tokyo dropped from 5,063,495 as of 1 January 1945 to 2,310,734 on 1 August 1945. It appears from these figures that the attack of 9-10 March 1945 resulted in a large exodus of persons from the Tokyo area thereby causing an acute man-power shortage for industrial operation. This is borne out by statements of plant managers that production in plants was seriously curtailed or stopped completely. The manager of the Fukagawa works, Mitsubishi Steel company, stated that his plant did not operate after 9 March, although the property was not damaged in the attack.

9. Any figures on loss of life in a conflagration of this magnitude are necessarily estimations. Japanese figures, obtained from the Metropolitan Police bureau, are believed to be the most accurate available. All attacks on Tokyo caused 93,056 deaths and 72,840 injuries. The attack of 10 March resulted in 83,793 deaths, or 90 percent of the deaths caused by all air attacks on Tokyo, and 40,918 injuries. The number of homeless from all attacks was 2,891,000, of whom 1,008,000 were made homeless by this one attack. A total of 201 firemen were killed in all air attacks on Tokyo. Of that total 85 were killed and 40 missing in the 9-10 March attack. Total casualties to auxiliary firemen in the attack were in excess of 500. No figure was available for total casualties to this group in all attacks. The great loss of life is attributed to the rapid spread of fire, its great intensity, and the large area covered. Persons attempting to flee from the attacked area were burned in the streets by the intense heat (Photos 43, 44, 45, and 46), although some were able to escape through the fire lanes. Many fled to the canals and were literally scalded to death or died from the effects of hot gases (Photo 46).

10. The following plants, damaged in the attack of 9-10 March, were investigated:

a. Target 3, Hitachi Engineering Works, Ltd., Kameido Plant. This plant manufactured naval accessories such as air coolers, compressors, and ventilating systems. There was no damage to any of the main buildings, but 240 M69 bombs fell in the vacant yard south of the plant buildings and totally damaged several small auxiliary buildings of wood-frame construction. None of these bombs was a dud. The plant was not damaged by exposure fire—either radiation or flying brands. The area surrounding the property offered almost complete protection from exposure fires by means of a 150-foot, man-made firebreak, a canal, and a railroad embankment. The property surrounding this area was a mixture of poorer-class factories and workers' homes, all of which were totally damaged. The bombs which dropped in this area came from the last of the bombers at about 0115 hours. The first warning the plant had was the beginning of the attack on the city, but this gave them considerable time to prepare their defenses. The employees had been well trained in fire fighting and it was evident that they had functioned better than most, although they were aided by having more time to make preparations and by the firebreaks and the bomb pattern.

b. Target 6, Mitsubishi Steel Works, Fukagawa Plant. The products of this plant were steel bars and cylinders used by other concerns in the vicinity for manufacturing various items for the ship-building industry. This plant was not damaged except for an isolated frame warehouse which was completely burned as a result

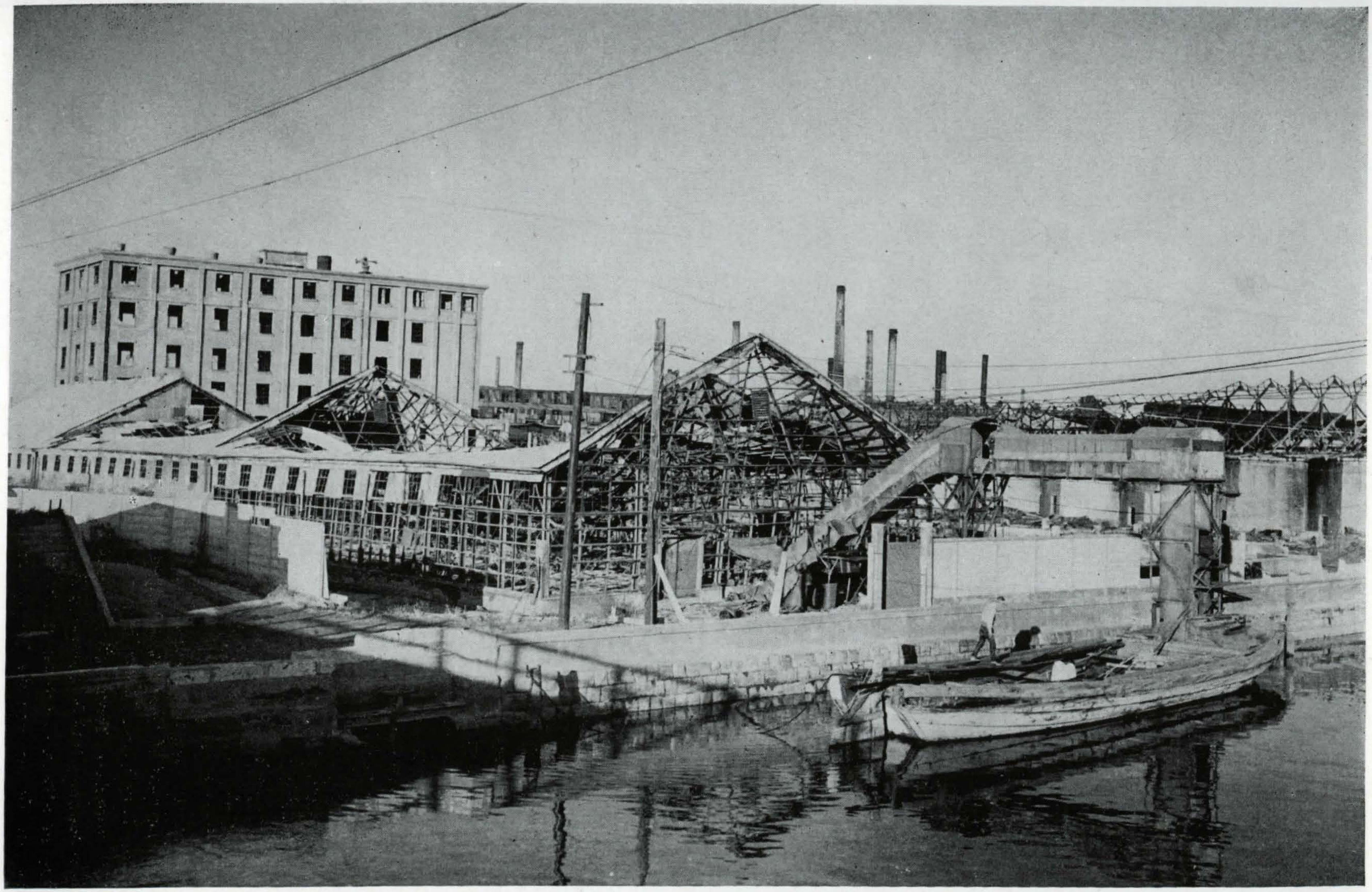


Photo 40.—Typical single-story steel-frame building with thin roof covering. Very few bombs struck this building, but it suffered heavy damage. The fire-resistive building in the left background burned from exposure fires.

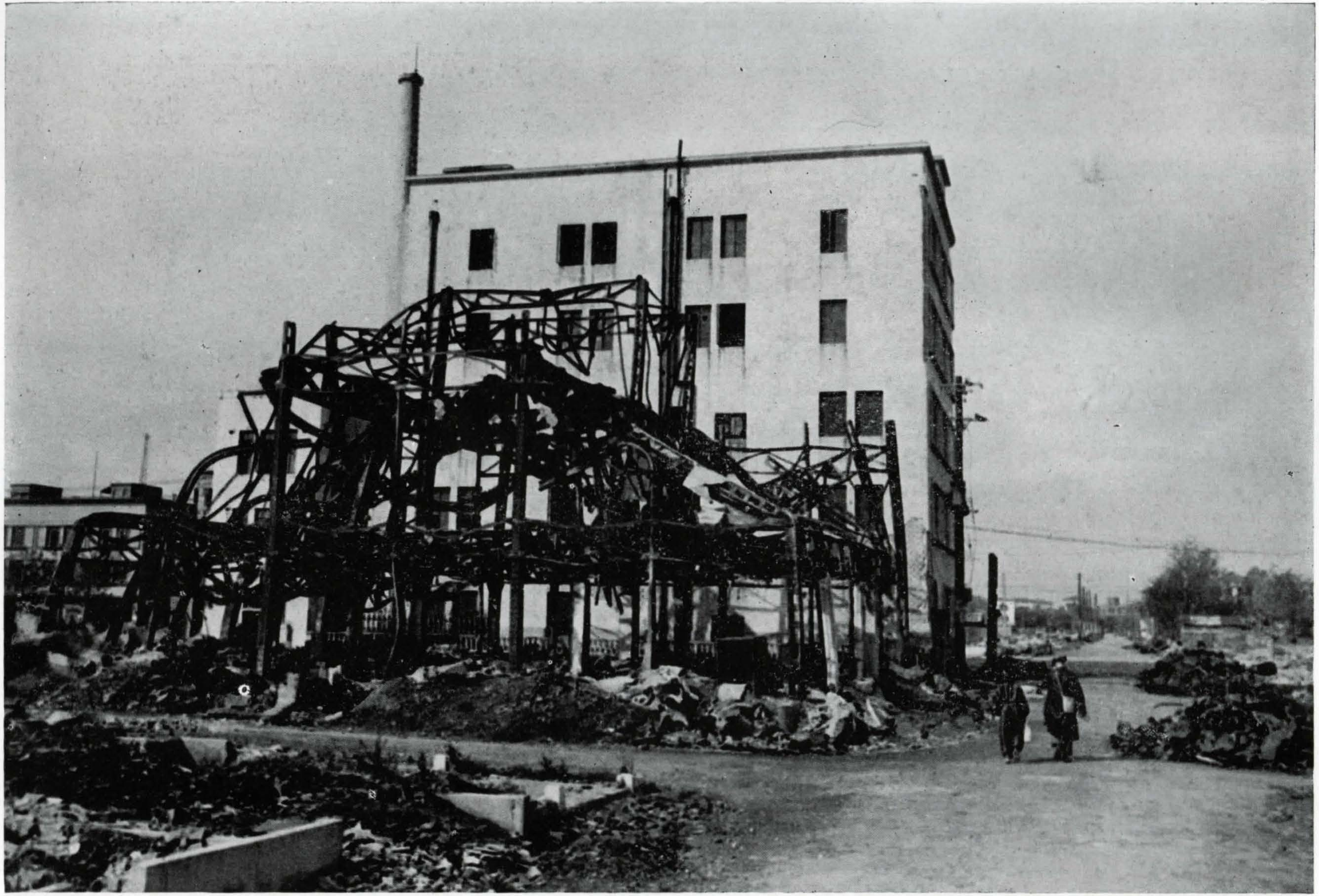


Photo 41.—Steel-frame building adjacent to a fire-resistive structure with protected openings. The steel-frame building was destroyed; the other suffered very minor damage.

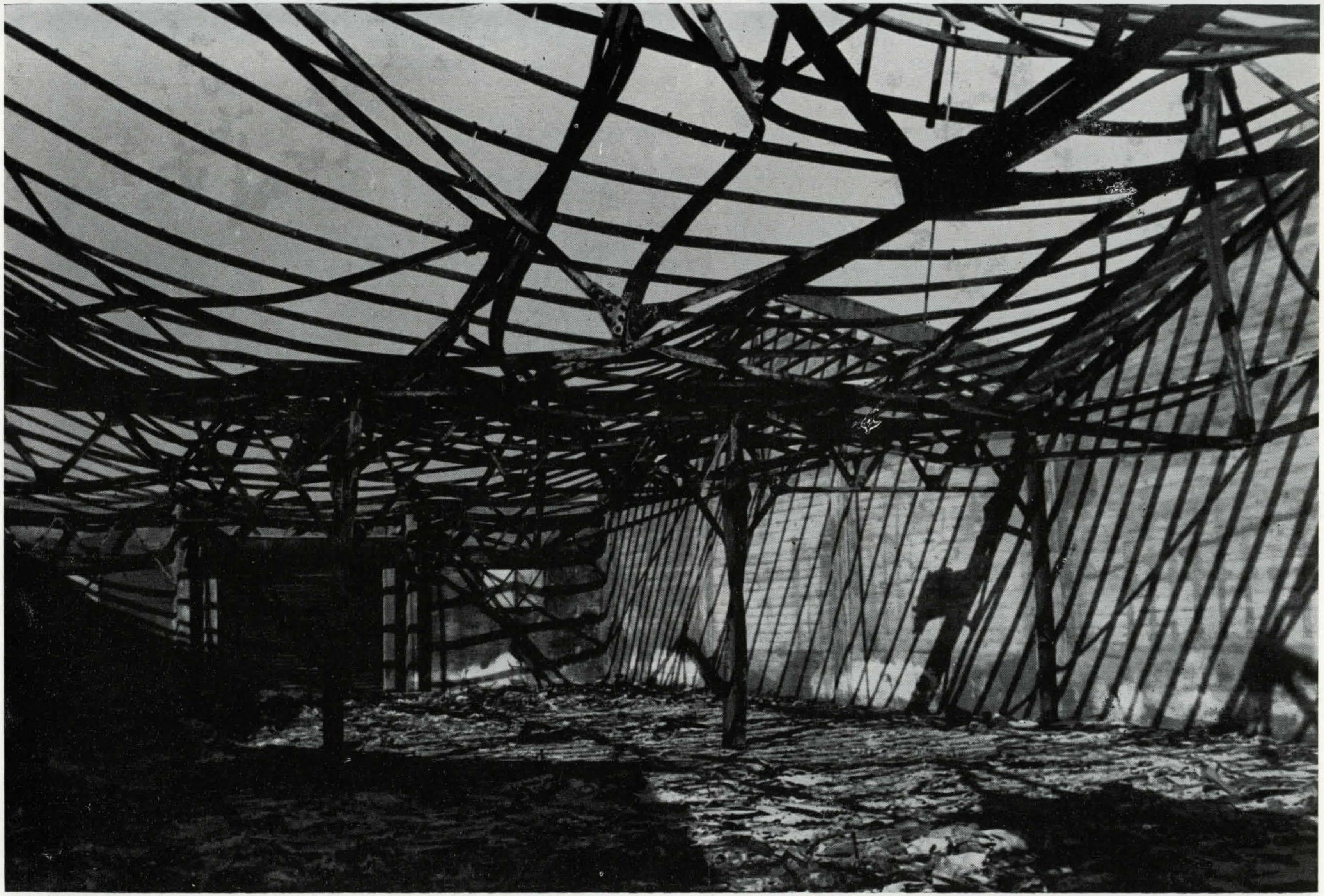


Photo 42.—Typical light one-story industrial building damaged by fire. The contents were combustible. Both the roof and walls were structurally damaged. Note the cracked roof covering on the floor.

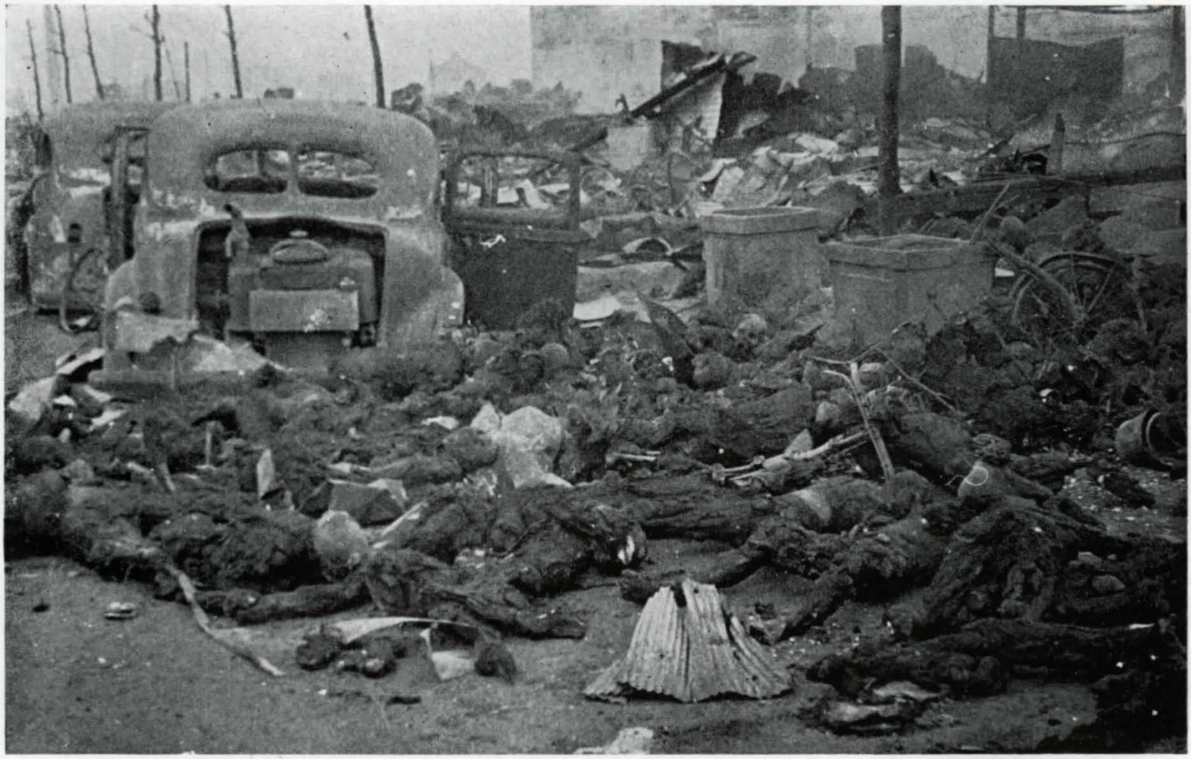


Photo 43.—Japanese photo showing bodies of people trapped and burned as they fled through a street during the attack of 9-10 March. Note that automobiles and bicycles were also trapped and burned.

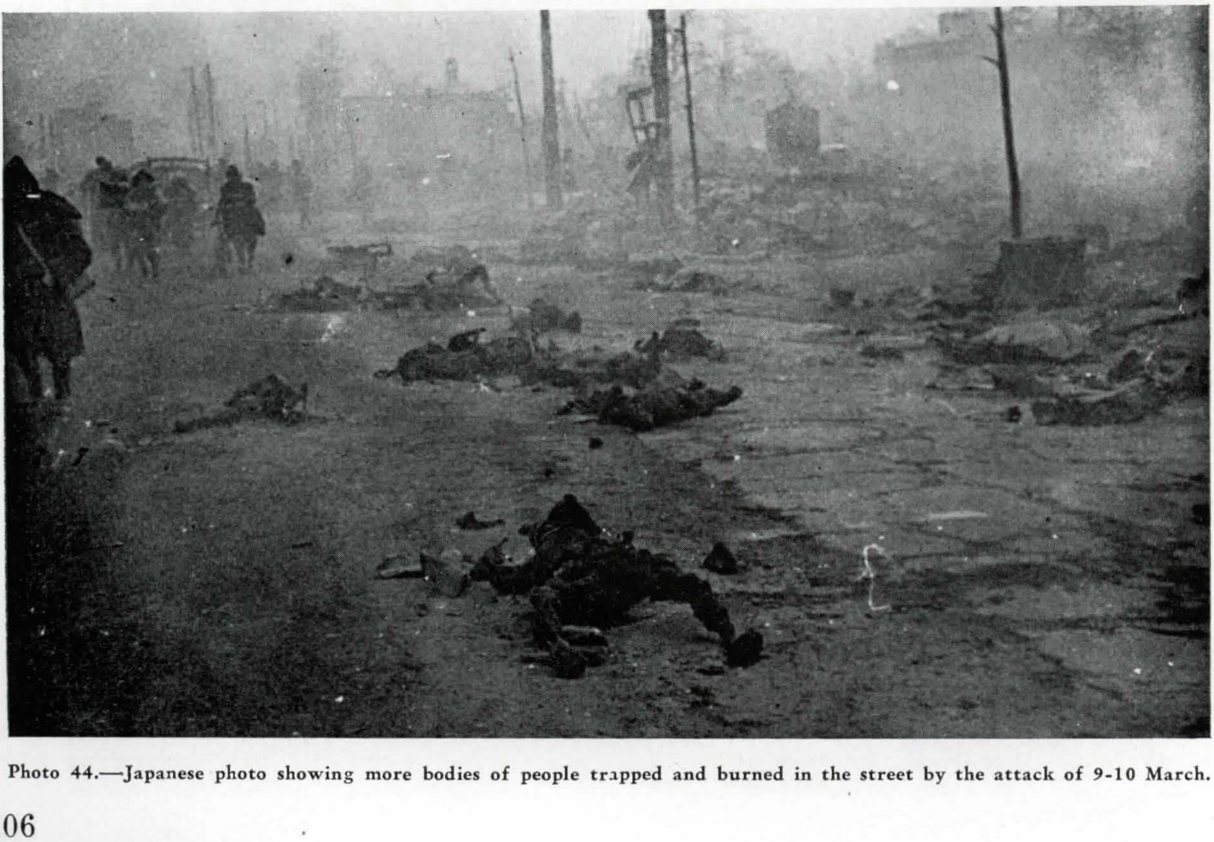


Photo 44.—Japanese photo showing more bodies of people trapped and burned in the street by the attack of 9-10 March.

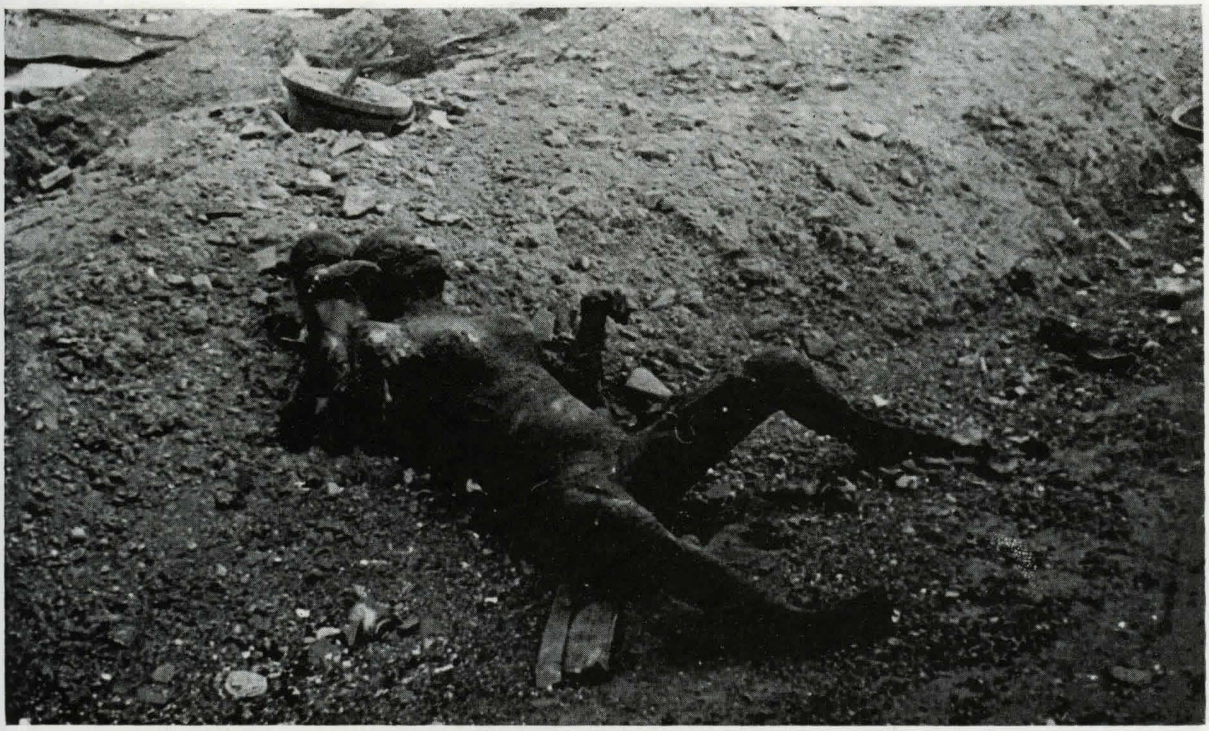


Photo 45.—Japanese photo showing close-up of burned bodies. It is believed that these people were killed by inhaling hot gases and burned later.

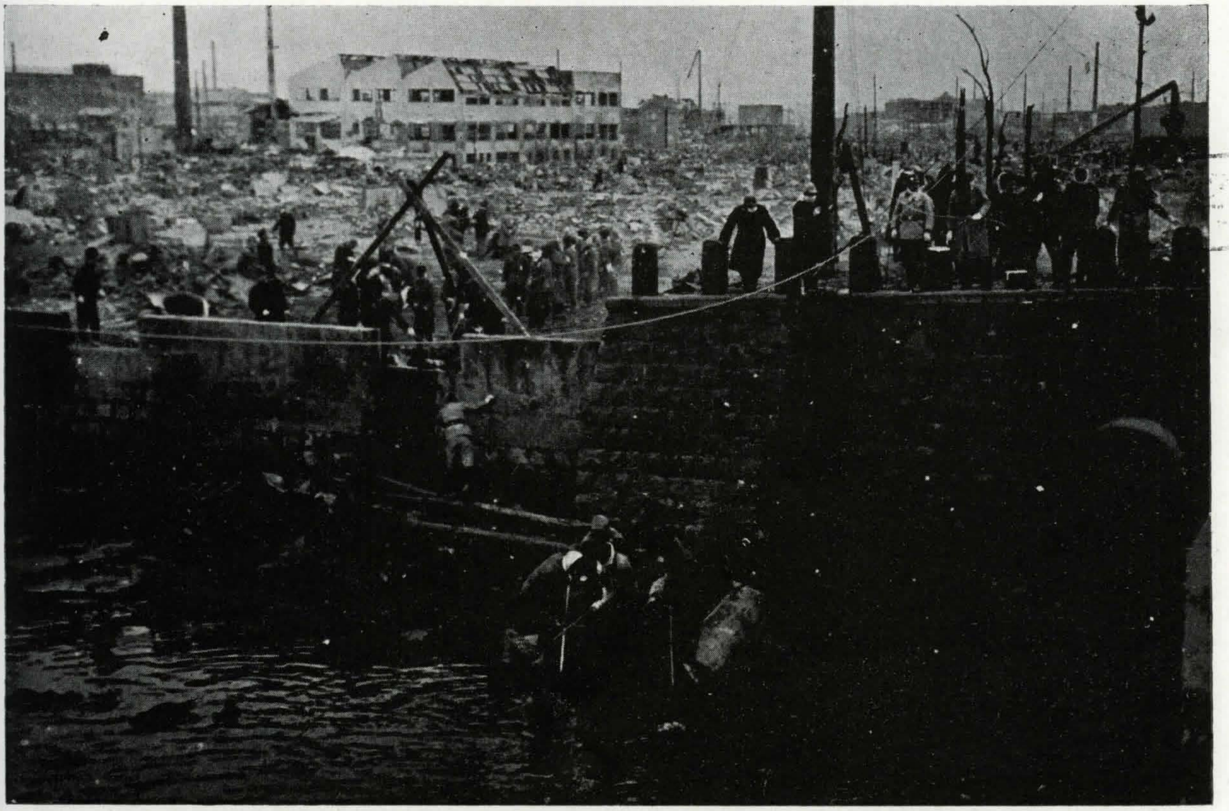


Photo 46.—Japanese photo showing dead being removed from canal. People fled to canals and rivers attempting escape and many were either burned or asphyxiated.

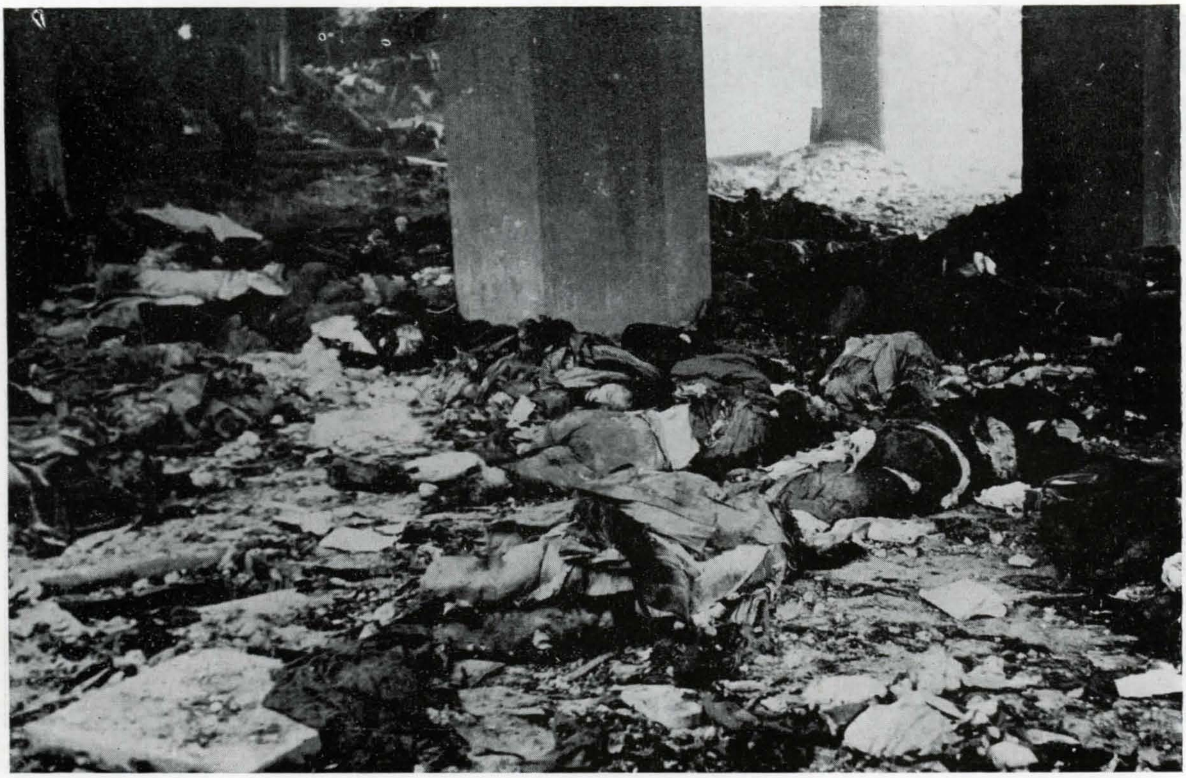


Photo 47.—People killed in railway station by hot gases. Note the shattered roof covering on the floor.

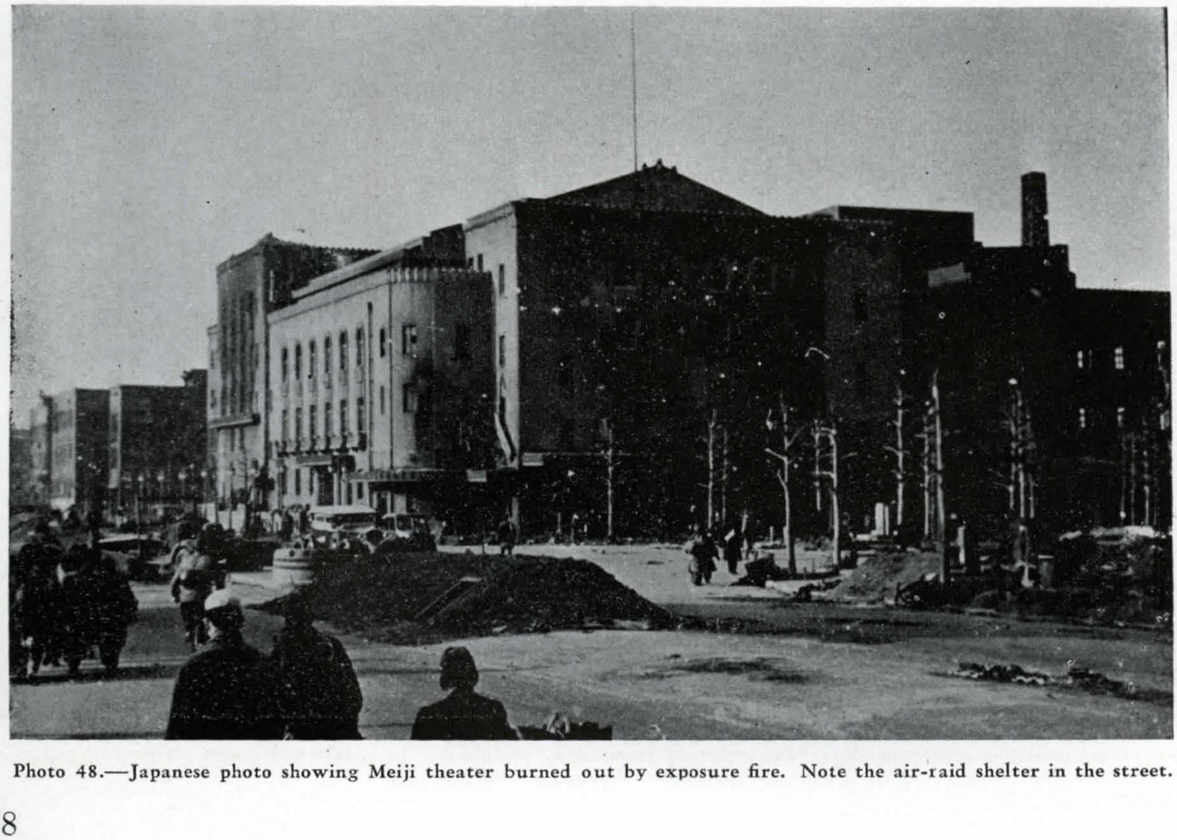


Photo 48.—Japanese photo showing Meiji theater burned out by exposure fire. Note the air-raid shelter in the street.

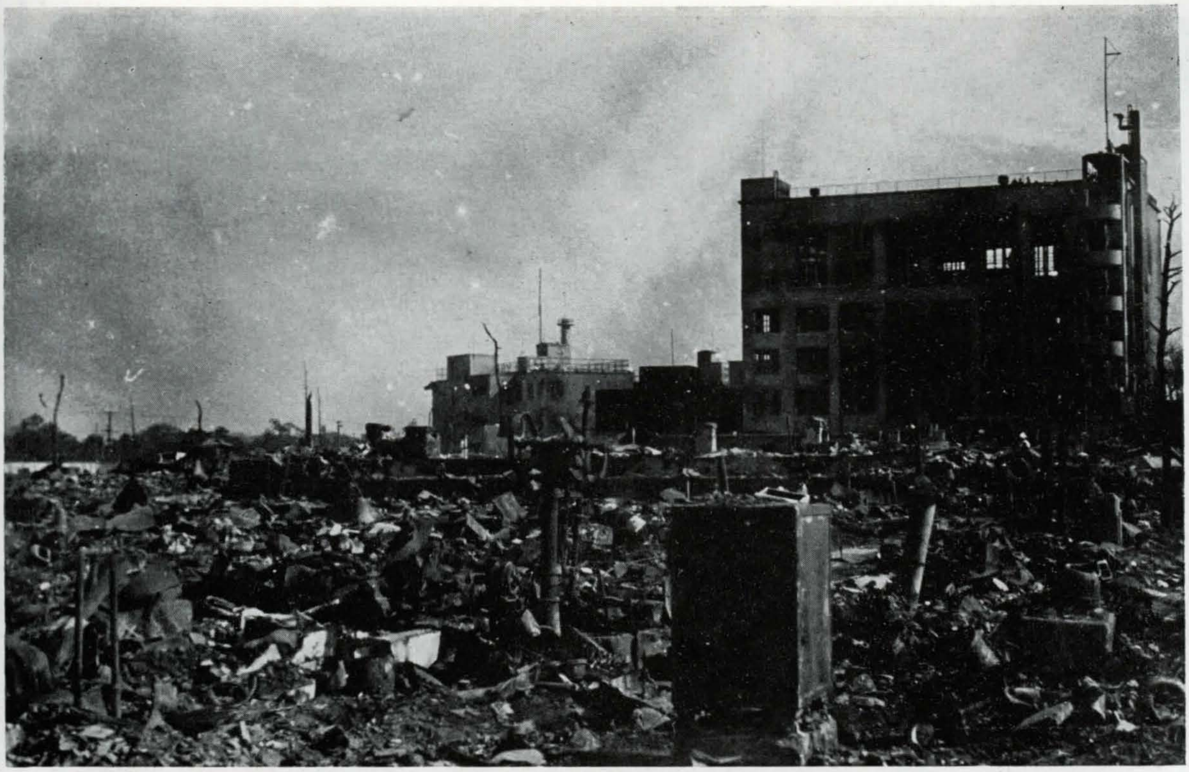


Photo 49.—Japanese photo showing ruin of a home industry in the foreground and burned-out fire-resistive structures in the background.

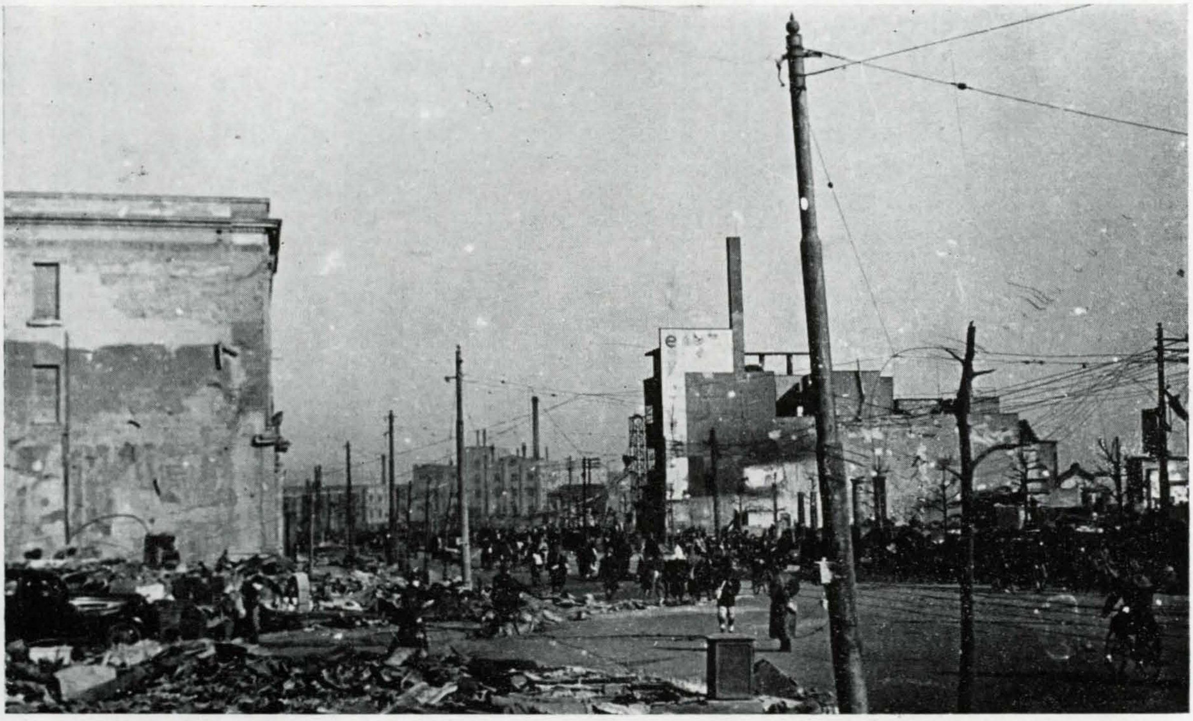


Photo 50.—Japanese photo showing a general view of the ruins on the morning of 10 March. The fire-resistive structures were burned out.

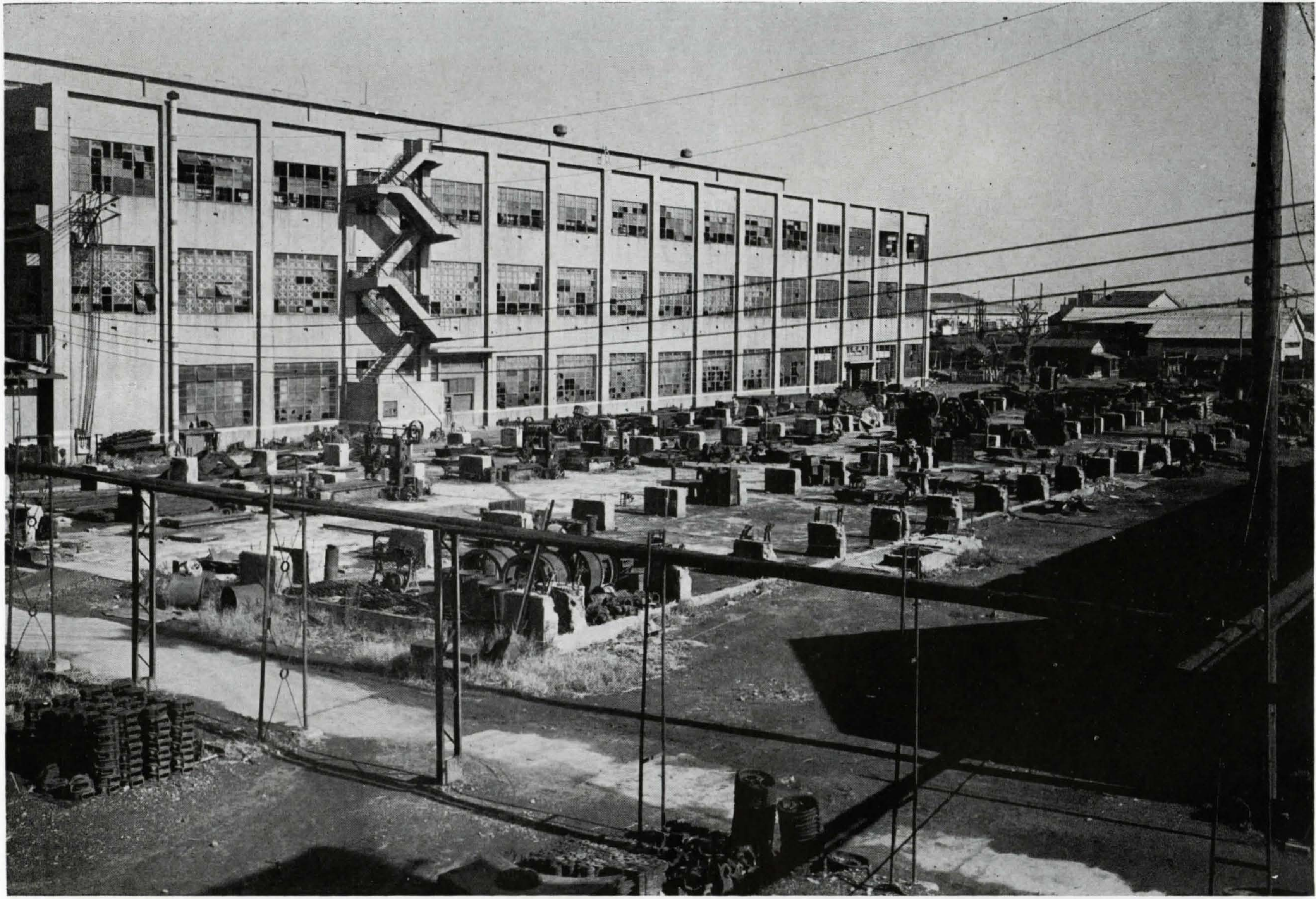


Photo 51.—Matsu generator factory. The area in the foreground was covered by a wood-frame building which was burned. This fire broke many of the windows in the factory (since partly replaced) but did no structural damage.

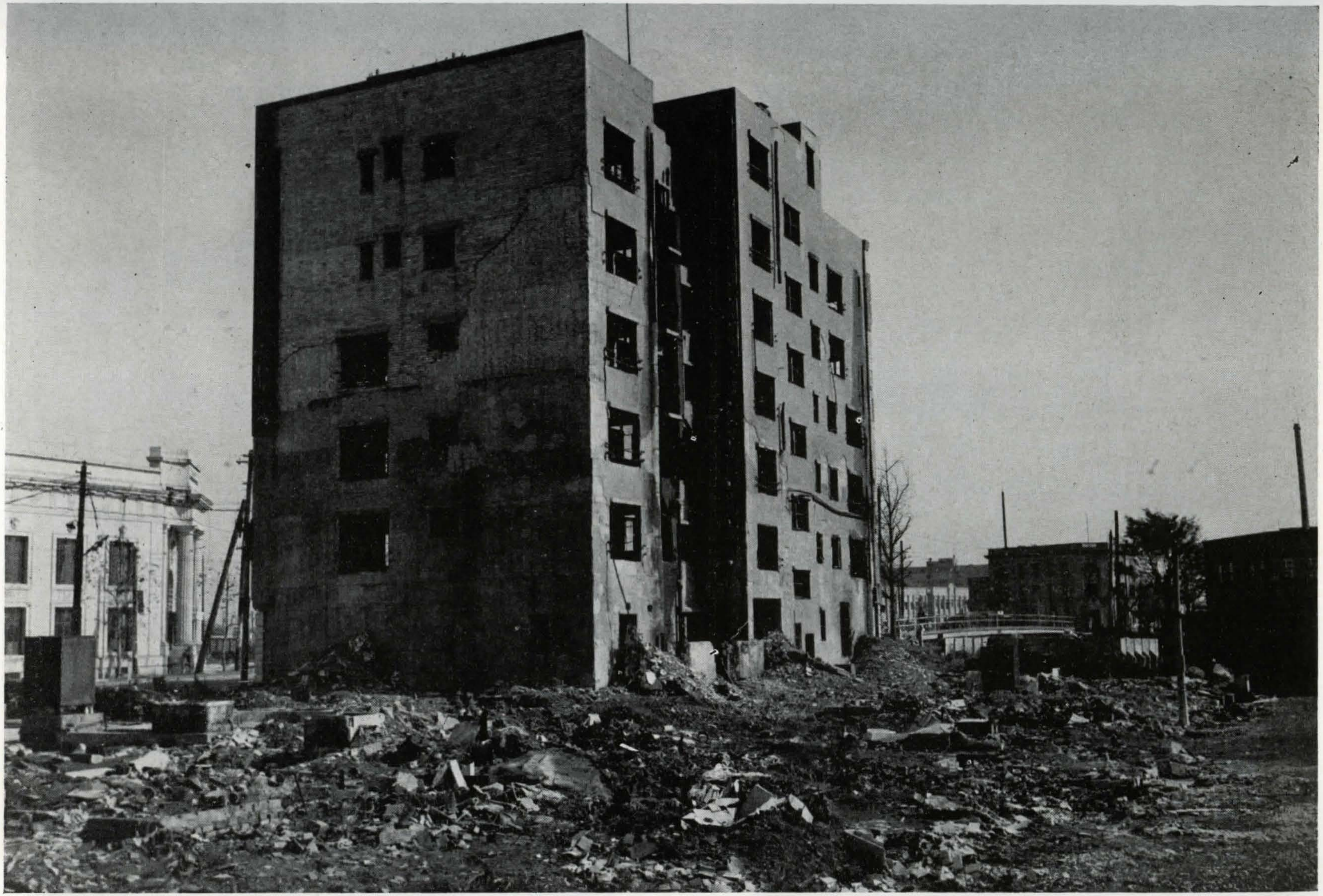


Photo 52. — A fire- and earthquake-resistive office building with unprotected openings, the interior of which was completely burned out by exposure fires. The Japanese did not normally use wire-glass windows or fire shutters on exposed openings.

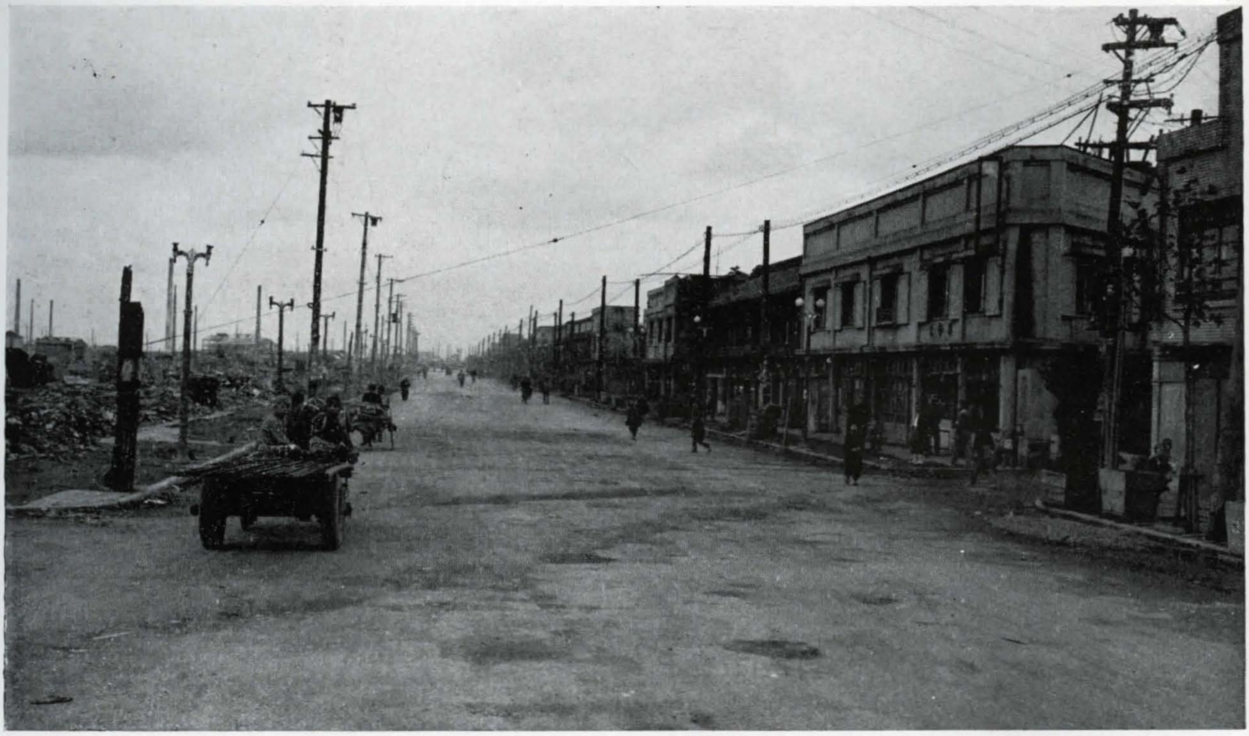


Photo 53.—The effect of a wide street on the spread of fire. The wind at the time of attack was parallel to this street. Only a few scattered bombs fell on the unburned side of the street, and these were brought under control by individuals.

Photo 54. — The same street shown in Photo 53 viewed in the opposite direction.

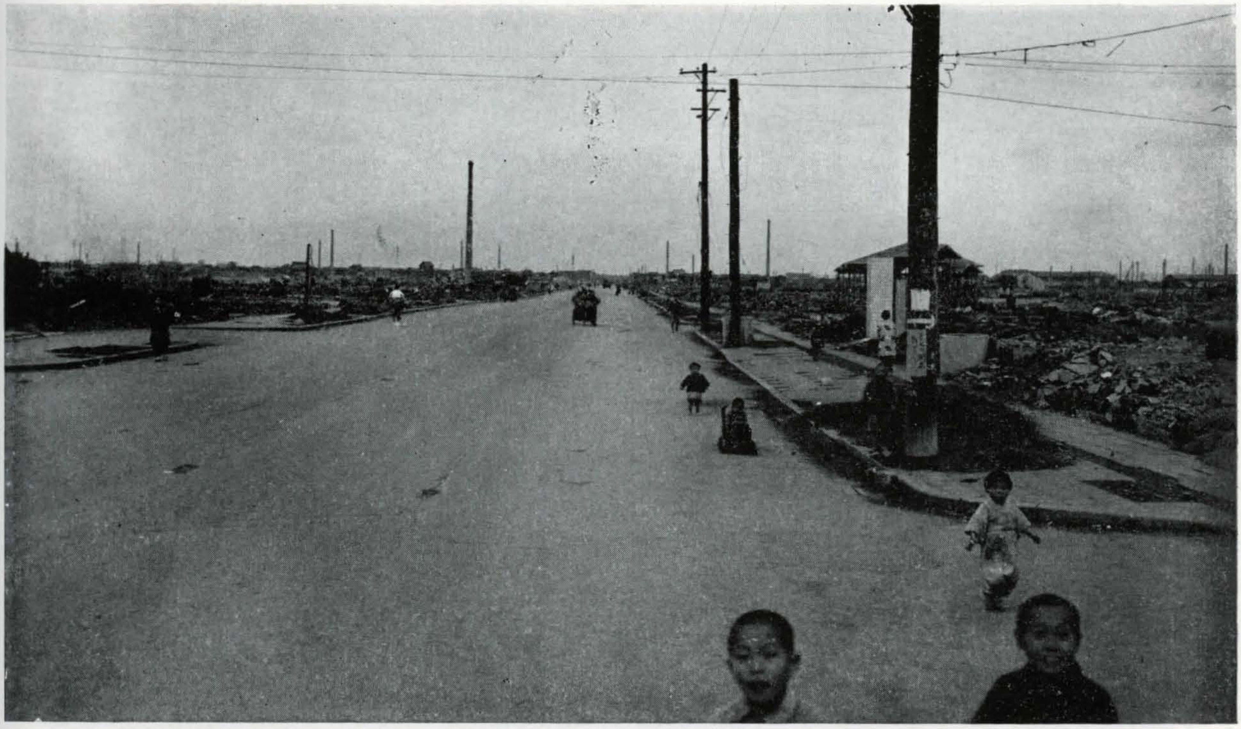


Photo 55.—Wide street in the burned area where the wind was blowing at right angles at the time of the attack.

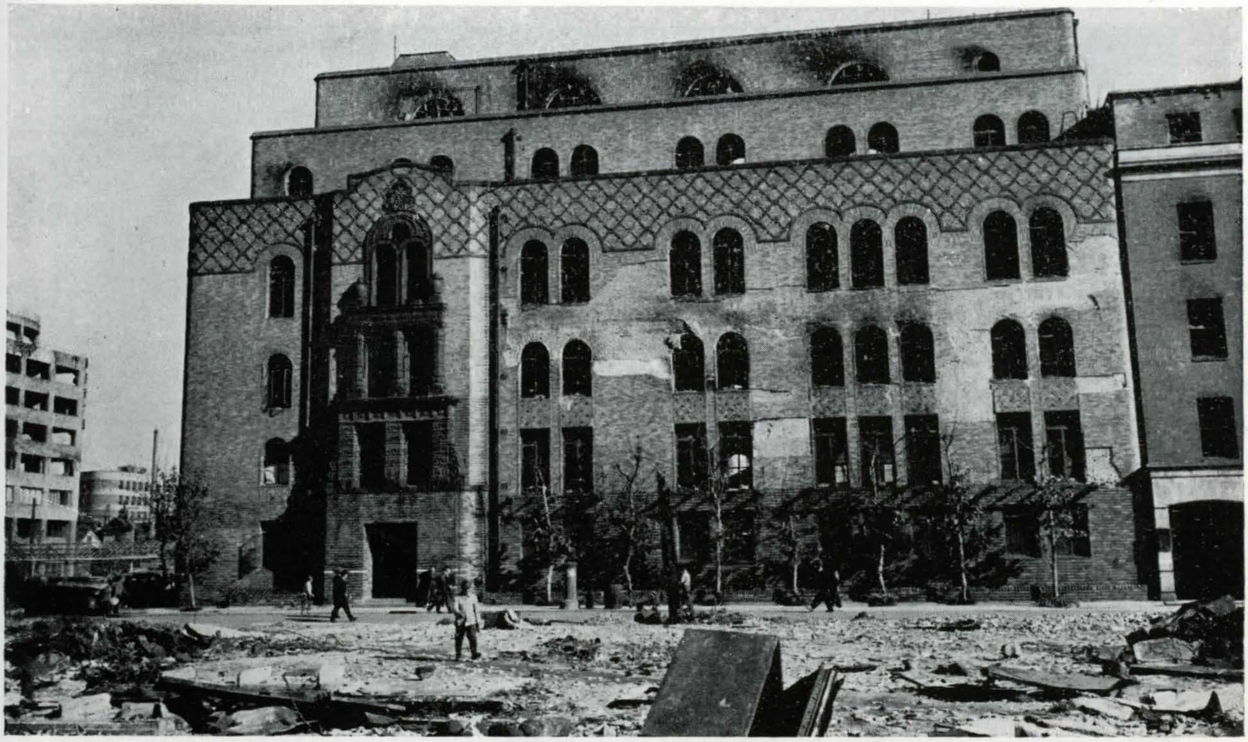


Photo 56. — Tokyo Electric Company building. This building was struck with a 500-lb. M76 incendiary bomb in an attack in January 1945. The bomb perforated the reinforced-concrete roof, ignited on the top floor, and burned out the interior of the entire building.

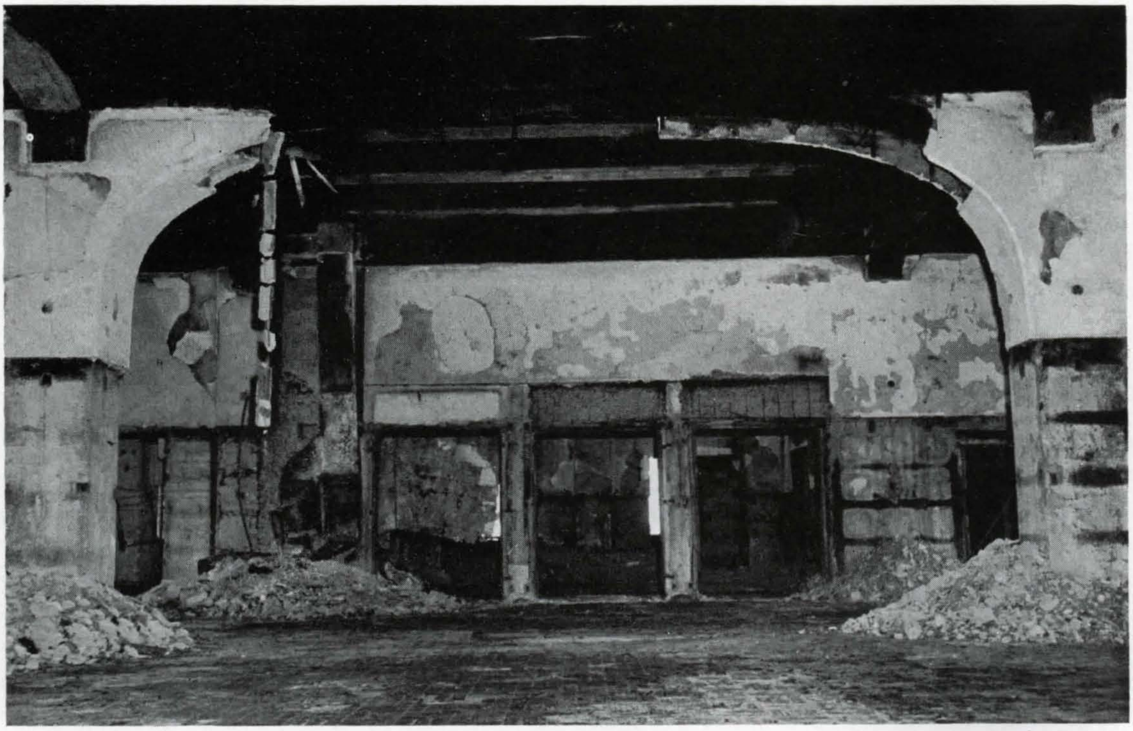


Photo 57.—Third-floor interior of the Tokyo Electric Co. building showing how the building was burned out. The building was fire-resistive. There was no structural damage.

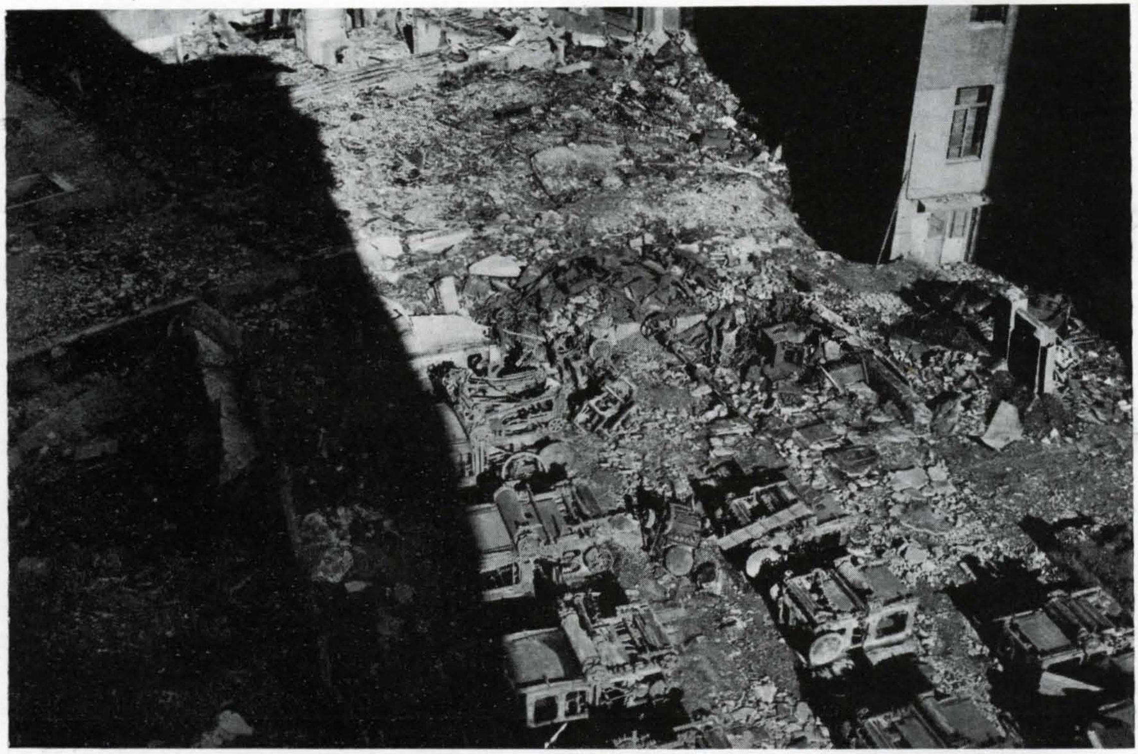


Photo 58.—Remains of a newspaper plant adjacent to the Tokyo Electric Co. building. This plant was a wood-frame building and was burned by exposure.

of fire caused by one bomb. About 400 bombs were scattered over an adjoining open area and over a small neighboring spinning mill which was about 60 percent damaged. The steel plant ceased production after the attack because of a shortage of help brought on by the displacement of laborers.

c. Target 5, Fujikura Electric Cable Works. This company employed about 4,000 persons prior to the attack, but had not operated since. It manufactured electric cable and wire of all types and sizes. A small number of M69s fell among some small shops and warehouses across a narrow canal from the buildings of the main plant. The plant manager said that most of these bombs were extinguished. Only one of the buildings in this area was totally damaged. The canal was so narrow, however, that a strong wind blew flames from this building across the canal, and the main plant buildings were ignited by exposure. These main buildings were of reinforced concrete with either wood-truss roofs covered with corrugated-asbestos cement or steel-truss roofs covered with corrugated sheet iron. All the roofs were stripped, but the steel trusses were still intact with little deformation and could have been re-covered. In almost every instance walls and roofs of corrugated-asbestos cement shattered and collapsed from the heat. It was estimated that 80 percent of this plant was totally damaged. All the machines were heavily damaged except for a few in the winding building.

d. Target 4, Shibaura Electrical Works. (Shows on G–2 reports as Japan Sugar Co.) This plant produced tungsten for lamp and vacuum-tube filaments and molybdenum and tantalum concentrates. It also made synthetic rubber for gaskets, packing, and hose. The main portion of the plant was not damaged, but a warehouse and a laboratory collapsed as a result of fire. Both of these buildings had reinforced-concrete walls and reinforced-concrete roofs on unprotected steel trusses. The sagging of the trusses released the roofs and collapsed the walls (Photos 37, 38, and 39). The source of heat in these buildings was not completely explained. The manager said that the two structures were used largely for the storage of ore, but it is known that they also contained pitch and calcium carbide. The manager stated that the bombs entered through the windows. The roof was a 6-inch concrete slab and had no skylight, so M69s should not have been able to perforate it, and there were no other structures near enough to cause an exposure fire. Plant damage was estimated at 20 percent.

e. Target 2, Hattori Co. (Seikosha Watch Mfg. Co.). This company manufactured time fuzes for artillery shells including 20-, 25-, 40-, 57-, and 77-mm. shells. About 4,000 people were employed. Ten M69 bombs struck the plant, and were all extinguished by plant personnel. The main plant building, however, was ignited by an exposure fire across a 75-foot open space (a street and cleared area). The heat here was great enough to melt wire-glass windows and to enter the plant proper. All the plant buildings were fire resistive throughout, the construction being reinforced concrete with wire-glass windows. After the fire entered, it burned through the buildings and heavily damaged most of the machinery. The buildings were only superficially damaged. The management estimated the damage at 35 percent. Operation continued on a reduced scale until 14 August 1945.

f. Target 1, Oana Manufacturing Co. (Nippon Electric Works). This plant produced small motor-generator sets of 1, 3, 6, 8, and 25 KW for the Navy. It employed 2,200 persons. Between 200 and 300 M69 bombs fell on the plant area and ignited the wooden buildings. This put the plant fire-fighting equipment, which was housed in one of them, out of commission and also started fires in the adjacent fire-resistive structures through exposure. About 40 percent damage was suffered by buildings and contents. The fire-resistive buildings were only superficially damaged, but the machinery was heavily damaged. Production was reduced to an output of about 20 percent of normal.

VII. Conclusions

1. The high efficiency of the attack of 9-10 March was due to:

a. The great combustibility of the buildings in the target area.

b. The high built-upness of the target area, i.e., more than 40 percent.

c. The ideal weather conditions, i.e., a high wind, clear, dry.

d. The large size of the target area and of the city surrounding it, making it almost impossible to drop bombs where they would do no damage.

e. The wise choice and efficient performance of the tactics involved—four aiming points, briefing to drop bombs individually in areas of target where fires were not already burning; low level for greater accuracy; and an all-incendiary bomb load.

f. The ineffectiveness of the fire-fighting forces and equipment.

2. Fire-resistive buildings in burning areas were often ignited by exposure fires, sometimes over an open area as great as 75 feet.

3. Fire-resistive buildings when subjected to contents fires, generally suffered only internal damage.

4. Many home industries were destroyed in attacks on residential areas.

5. Loss in production at undamaged factories was heavy because of the displacement of workers.

TABLE I.—SUMMARY OF ATTACKS.

Mission number	Date	Planes over target	Approximate true heading	Approximate surface wind from—	Number of aiming points	Altitude (1,000 feet)	Intervalometer (feet) P = Pathfinder; M = Main force	Bombs used					Total tons dropped	Clusters to open at (feet)	Time over targets (minutes)	Damage (square miles)	Damage per 1000 Tons Bombs (square miles)	Remarks
								Total tons (M69)	Total tons (M47)	Total tons (M50)	Total tons (M76)	Total tons (HE)						
38	25 Feb.	172	SE.	NW.	1	23.5 31.0	25	412	------	------	------	42	454	5000	114	1.0	2.20	Day attack, complete overcast, all radar bombing, no fighter opposition, flak meager, 91 percent M69's.
40	9-10 March	279	NW.	SW.	4	4.9 9.2	100 P 50 M	1539	128	------	------	------	1667	2000 2500	173	15.8	9.48	Night attack, 3/10 overcast, half visual-half radar bombing, smoke and thermals, fighter opposition weak, flak intense, 92 percent M69's.
67	13-14 April	327	NW.	NW.	3	6.8 11.0	100 P 50 M	1820	222	------	------	82	2124	2500	219	11.4	5.37	Night attack, 5/10 overcast, 2/3 radar bombing, excessive smoke and turbulence, fighter opposition moderate, flak intense, 86 percent M69's, 164 M69's and 77 M47's dropped safe.
69	15-16 April	109	NE.	NW.	1	8.0 10.1	100 P 50 M	434	320	------	------	15	769	2500	142	6.0	7.80	Night attack, clear, all radar bombing, thermals bad on breakaway but visibility good, some planes arrived too early, flak and fighter opposition intense, searchlights blinding, 56 percent M69's.
181	23-24 May	520	E.	NW.	6	7.8 15.1	100 P 50 M	2820	777	49	------	------	3646	5000	119	5.3	1.45	Night attack, 9/10 overcast, almost all radar bombing, initial point not identified in many cases, smoke especially bad, blinding searchlights, flak and fighter opposition intense, 77 percent M69's.
183	25-26 May	464	NE.	NW.	6	7.9 22.0	100 P 50 M	1320	634	945	348	4	3251	5000	155	16.8	5.17	Night attack, 3/10 overcast, 3/4 radar bombing, smoke fairly bad, flak and fighter opposition very intense, 41 percent M69's.
------	------	1871	------	------	------	------	------	8345	2081	994	348	143	11911	------	922	56.3	4.73	57 percent total load M69's.

Part 4

EFFECTS OF INCENDIARY BOMB ATTACK ON AOMORI, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 121

II. SUMMARY 121

III. GENERAL INFORMATION 121

IV. THE TARGET 121

V. WEAPON DATA 137

VI. ATTACK DATA 137

VII. DEFENSE AGAINST AIR ATTACK 138

VIII. THE FIRE 142

IX. DAMAGE 143

X. RECUPERABILITY 146

XI. CONCLUSION AND RECOMMENDATIONS 146

APPENDICES A, B, AND C

Photographs 1-33, inclusive

Figures 1-5, inclusive

Aomori Fire Damage Study

I. Object of Study

This study was made primarily for the purpose of evaluating the weapon effectiveness of the M74 incendiary bomb, and of surveying the fire damage accomplished by the attack made by the Twentieth AF on Aomori, Japan, on 28-29 July 1945.

II. Summary

1. The area of the city was computed to be 960 acres, of which 753 acres (or 78.4 percent) was built up. The greater part of this populated area consisted of combustible frame dwellings (one and two stories in height), small commercial establishments and a few small factories. Interspersed through this area were several medium-sized factories and, along the waterfront (Mutsu Wan), a few modern multistoried structures of reinforced concrete. There was also a number of well constructed wooden municipal buildings in the city.

2. The dispatched load of the Twentieth AF Mission 298 against the city of Aomori was 583.5 tons of M74 incendiary bombs. The load reported dropped on the target area was 546.5 tons.

3. This attack is of particular interest, inasmuch as it was the first time that the M74 10-pound incendiary bomb was used exclusively. This bomb was developed from the M69 and is described in detail in the body of this report. The principal differences between the two are that the M74 uses an all-ways fuze and a telescopic tail. White phosphorous was also added to insure ignition of the charge and to produce smoke in order to create antipersonnel effect and confusion.

4. Eighty-eight percent of the built-up area was destroyed as a result of this attack. Rail and ship ferry transportation and the general economy of the city were seriously crippled. Twenty-five ships in the harbor were burned beyond repair and two were partly burned. Railroad facilities were affected to the extent that 43 freight cars and 18 passenger cars were burned beyond repair; and 15 warehouses and 10 miscellaneous railroad buildings were completely consumed by fire. In addition, 19 fire department vehicles were so damaged by fire that they became unsalvageable; and 12 others were damaged, but less seriously.

5. There were 1,016 casualties, including 728 killed, 40 seriously wounded, 240 slightly wounded, and eight missing. Dwelling units to the number of 11,330 were literally consumed by the flames, thereby rendering 17,843 families homeless.

III. General Information

1. The team assigned this study was designated as Physical Damage Division Team 9 and consisted of the following personnel:

Capt. Robert H. Merz	Team chief-fire engineer
Capt. Elmer R. Hjortsberg	Fire engineer
Lt. (jg) Maurice H. Hellner	Interpreter
Lt. (jg) Gaspare B. Tamburello	Interpreter
PhoM 3/c William P. Mattern	Photographer
Sgt. John J. Cherry	Clerk
S 1/c Robert M. McClintock	Draftsman
S 1/c Wesley A. Feige	Draftsman

2. Able assistance was rendered the team by Lt. Col. Paul D. Stoddard, AC of S, G–2, of the 81st Division and officers under his command and also by Lt. Col. W. F. Atkins, the military governor, and his staff.

3. The information obtained in conjunction with the survey, other than by the physical inspection of the area, was secured from records and from interrogation of Japanese officials and civilians. The information from the Japanese was considered to be reliable.

4. No difficulty was experienced in obtaining the cooperation of the people interviewed, but, in a number of cases, records requested were unobtainable because of having been destroyed by the fire.

IV. The Target

1. *Geographical.* Aomori is located in the northern part of the island of Honshu in the southern curve of Aomori Wan, an indentation of Mutsu Wan which is one of Japan's largest and best protected bays. The immediate harbor for the city is called Aomori Ko. The two

bays are almost landlocked by two large peninsulas, running generally north of Aomori, separated at their tips by Tairadate Kaikyo straits, only five miles wide, forming the outlet into Taugair Kaikyo. The Komogome River runs northwest toward the city and is joined by the Ara River, the two forming the Tsutsumi River which borders the eastern edge of the main built-up area of the city. The area south of the city is mountainous (Figure 1, Photo 1).

2. *Built-upness or building ground occupancy.* Built-upness or building ground occupancy is defined as the fraction of plan area that has buildings. Sparsely built-up sections are areas upon which the built-upness ranges from 5 percent to 20 percent, while densely built-up areas range from 20 percent to 40 percent and higher. This city covers an area of 1.5 square miles of which 0.76 square mile (50.5 percent of the total area) is densely built up, and 0.42 square miles (28.0 percent of the total area) is sparsely built up. The remaining portion of the city (21.5 percent of the total) consists of open park and shrine areas.

3. *Population.* The normal population of Aomori was approximately 100,000. The city was, therefore, relatively compact with an overall population density of 67,000 persons per square mile.

4. *Industries.*

a. There is no general industrial development in the city of Aomori, comparable to that which is found a short distance south in central Japan. The primary industry of Aomori consists of small lumber mills and yards, fisheries, fish canneries, and food storage warehouses. Secondary industries include small factories employing five to 10 persons, and numerous unimportant "home workshops".

b. The city serves principally as a major choke point in the transportation corridor between central Honshu and the island of Hokkaido. Being the northern terminus of two railroads from industrial Honshu and the southern terminus of a railroad-car ferry shuttle from Hokkaido, Aomori provides a major strategic link between that island and the heart of Japan. In addition, there are moderately developed harbor facilities along the waterfront which provide lightering and berthing for small seagoing vessels. A small quay area behind a breakwater is used in conjunction with limited mechanical facilities for unloading coal (Photos 4, 5, and 6).

c. The general war status of Japan brought no appreciable change in the industry of Aomori, principally because of the fact that, industrially, prewar Aomori had been poorly developed. The lumber mills and yards continued operation in the early war years at only slightly increased rates of production, with the bulk of the finished lumber being shipped south by rail for use in large industrial centers. Two small lumber-working plants were engaged in the manufacture of wooden plane and glider parts, the largest single item being a wood seat. Net production of the item was negligible in so far as it contributed to the war effort. The Asiatic Can Co. (Photos 7 and 8) manufactured a cargo-plane landing-gear retriever piston and a wing-flap actuator piston. These were the only factories in Aomori which produced material for the war effort.

d. The greatest change effected in Aomori as a result of the war was the growth of the city's strategic importance as a transportation choke point, brought about by the restriction of seaborne coastal commodity traffic. Prior to the war, the total rail-borne through-tonnage between Hokkaido and central Japan had been greatly exceeded by seaborne traffic. The shift of the latter to rail routes, and the subsequent increased importance of storage and rail marshalling yard facilities in Aomori were by far the most important of all local industrial changes occasioned by the exigencies of war.

e. In addition to its vital role in railroad traffic, Aomori was of importance from a governmental standpoint, being the capital of Aomori Prefecture, of which the most important cities were Aomori itself, Hachinohe, and Hirosaki.

5. *Construction*

a. Dwellings. The typical Aomori dwelling was a one- or two-story frame structure with low-pitched, tile-covered roof (Photo 9). A raised floor of half-inch boards on light joists, a quarter-inch unfinished wood ceiling and the roof were supported by a light wood frame (Photo 10). Exterior walls were either of wood or wallboard, fastened directly to the main supporting structural frame, or were a

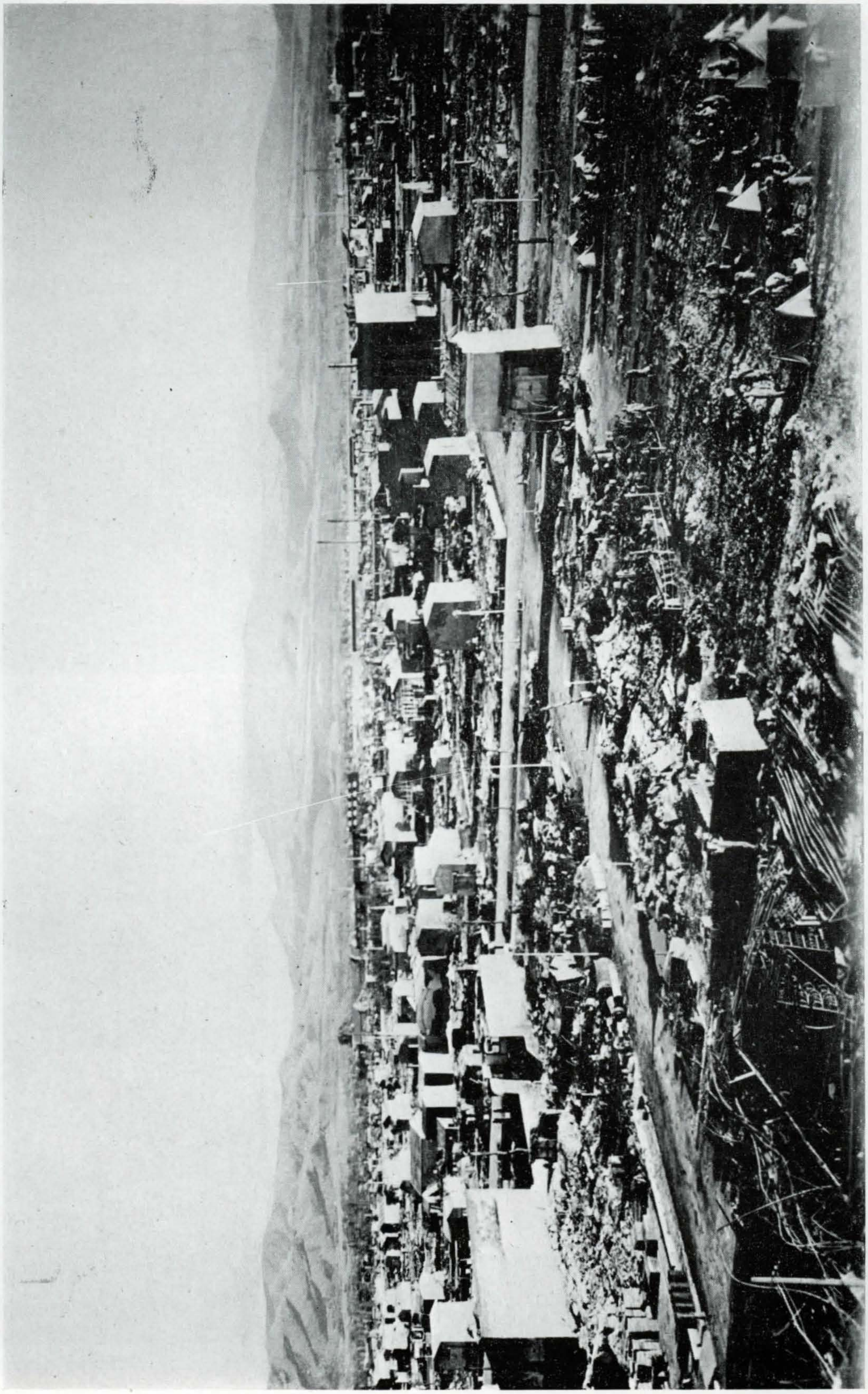


Photo 1.—Panoramic view, central portion of city.

Photo 2. — Typical congested urban district street scene.

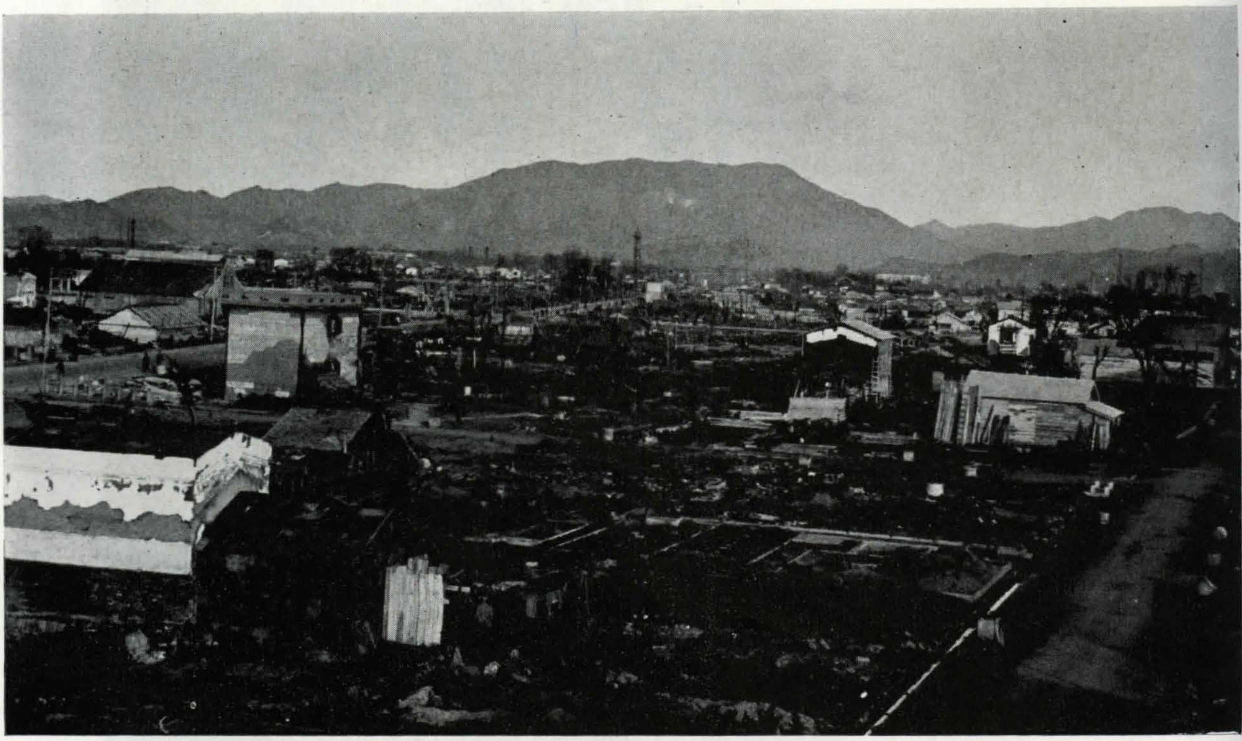


Photo 3.—General view showing street layout.

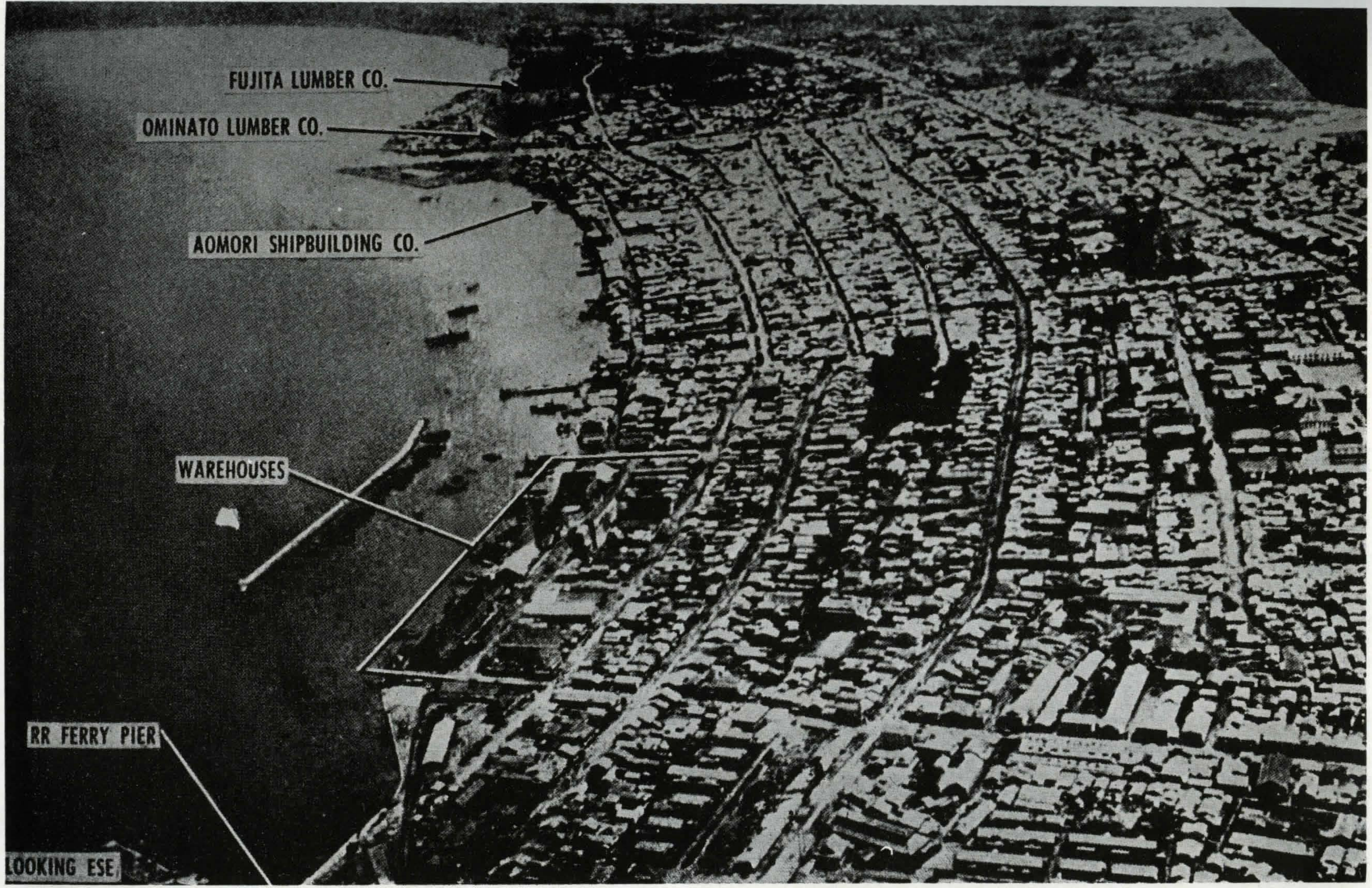


Photo 4. — Aomori and harbor . . . early pre-attack view.

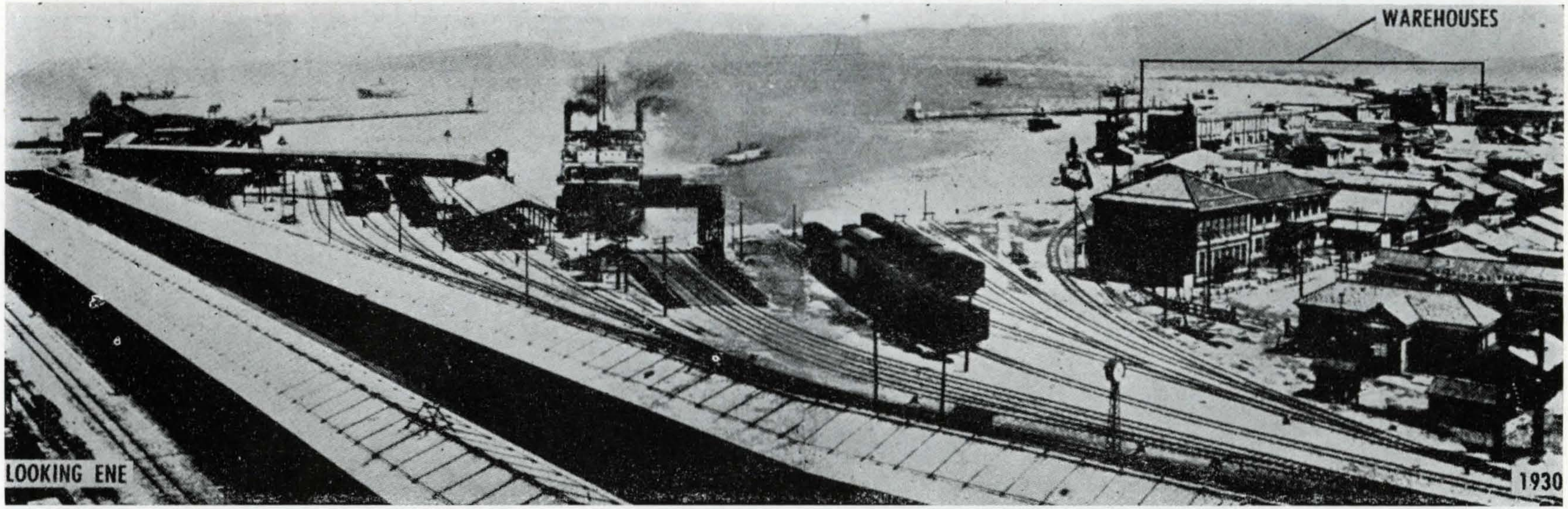


Photo 5. — Rail ferry terminus . . . early pre-attack view.

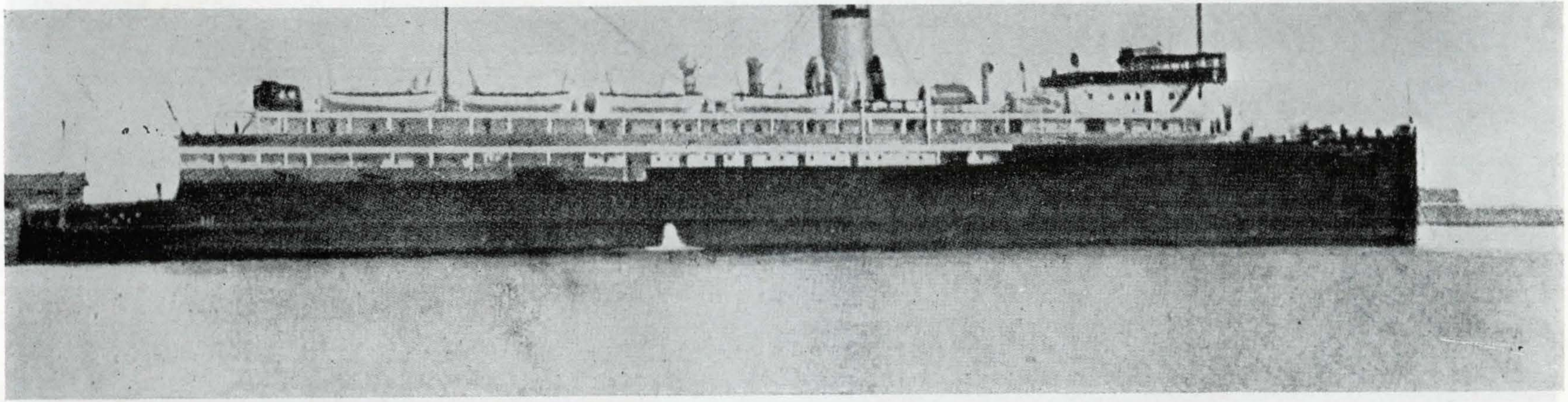


Photo 6.—Car ferry plying between Aomori and Hokkaido.

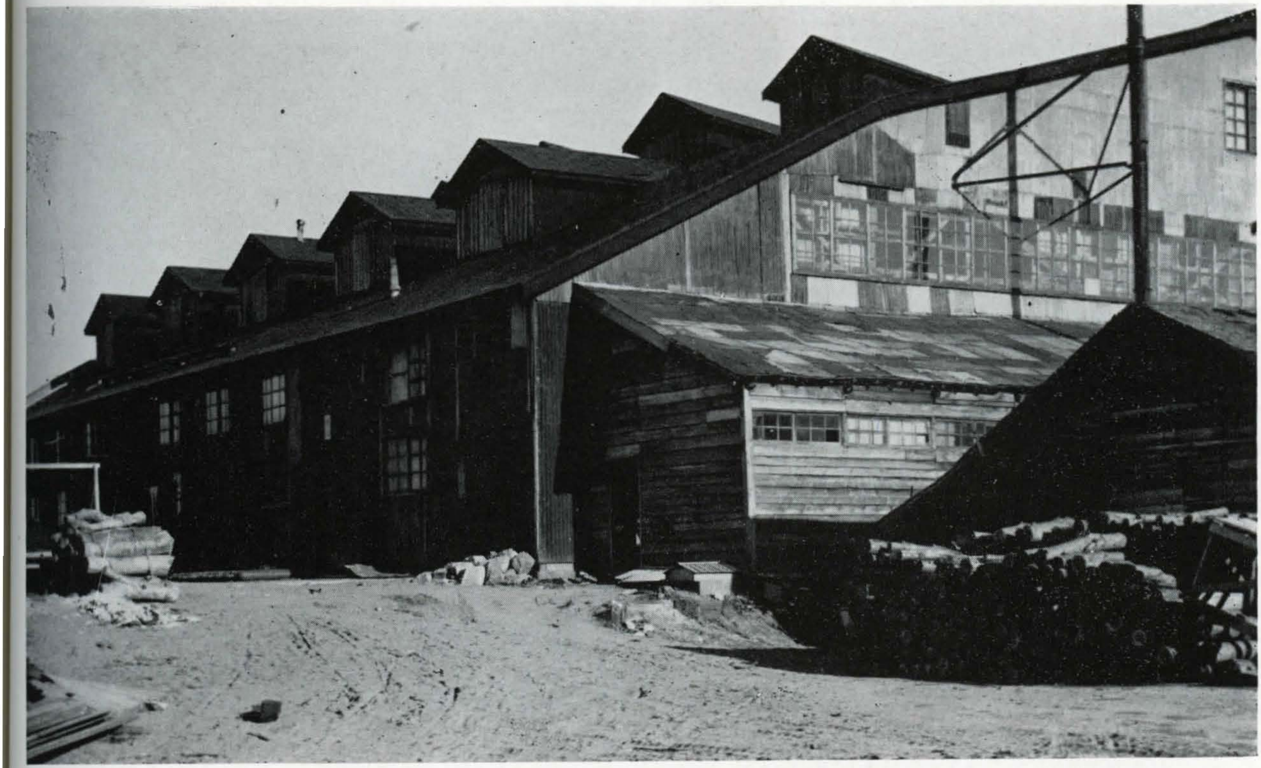


Photo 7.—Asiatic Can Co., typical industrial structure.

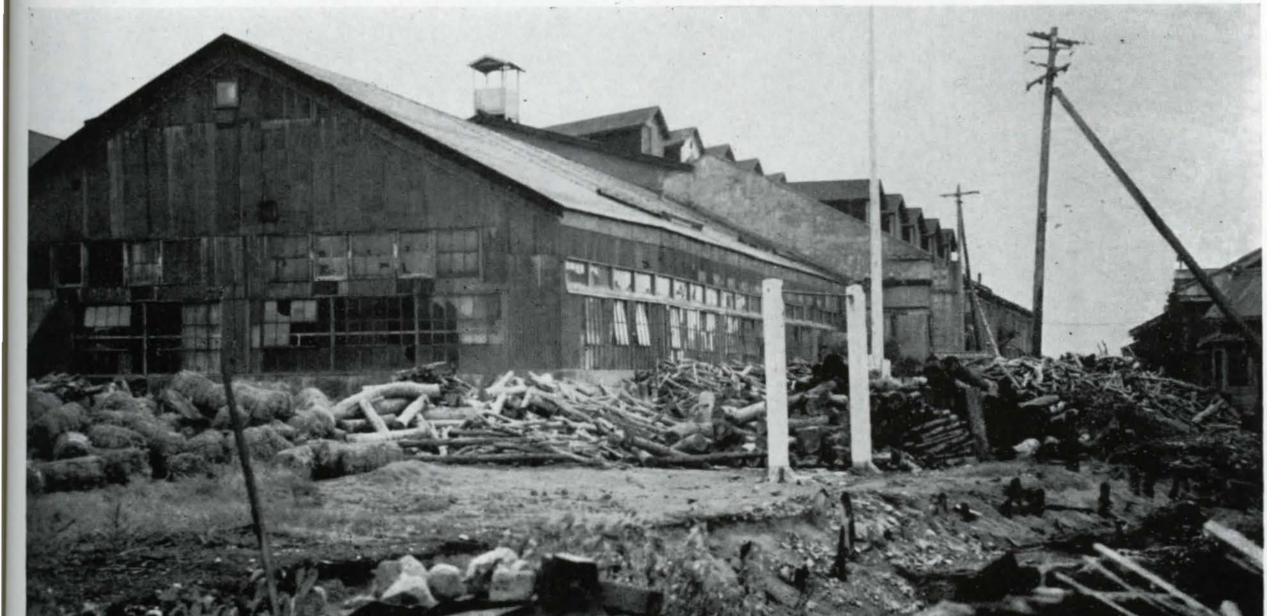


Photo 8.—Asiatic Can Co. Note partial fire wall of concrete between sections.

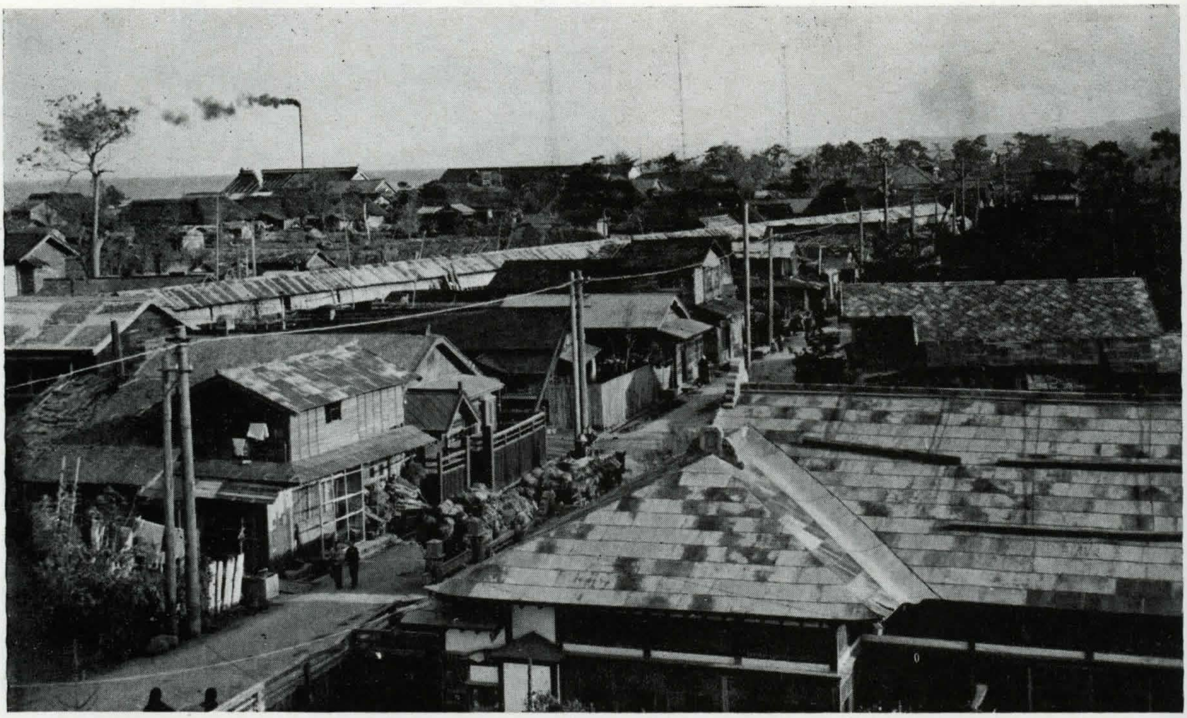


Photo 9.—Typical dwelling construction.

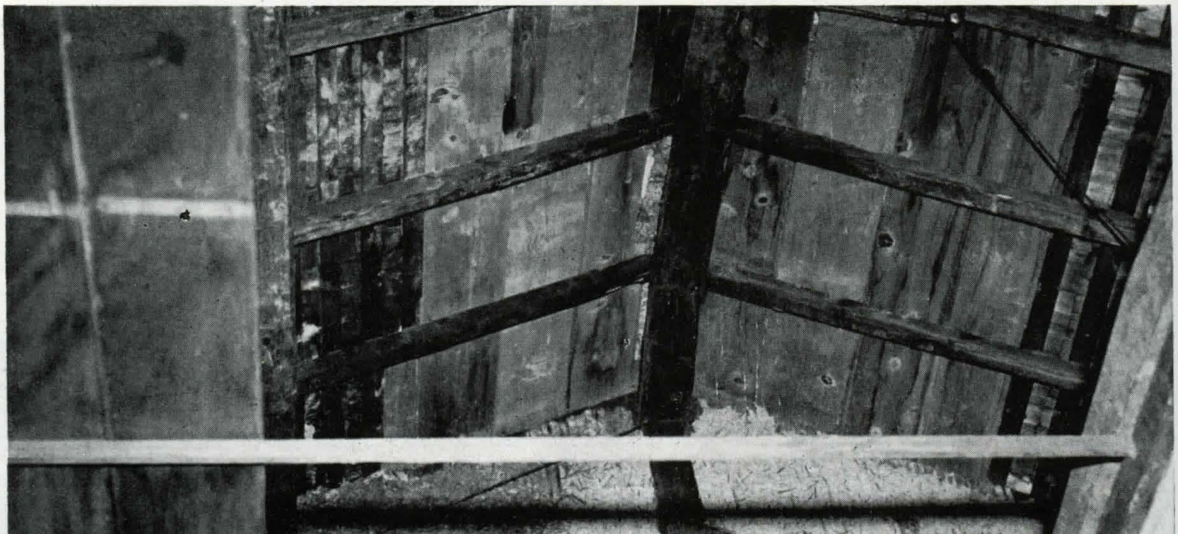


Photo 10. — Roof framing of dwelling. Note interior finish and partly removed suspended wood ceiling.

mud-mix carried on a bamboo lattice set between wood posts. Interior partitions were constructed of a lattice, made of quarter-inch wood or bamboo, and covered with either paper or wall-board. Sloping roofs were generally covered with tile or sheet metal over mud plaster on half-inch boards. In some cases, thatch board or bark roof covering was supported by light wood trusses carried on the wooden frame. Tiles were laid over a layer of mud on either wood or bamboo battens, or on half-inch wood boards (Photo 11).

b. Domestic workshops. The primary difference between domestic workshops and ordinary dwellings was the absence of the raised wood floor. The workshop floors were either concrete, laid on a rock or cinder fill direct on the ground, or were hard-trodden earth. These workshops, found either in dwellings or attached thereto, were noted in the more crowded areas in the center of the city.

c. "Godowns". A common Japanese vault-type structure used for the storage of valuable merchandise, clothing, and sometimes food was found in connection with several small mercantile and commercial structures, but also frequently adjoining dwellings. These "godowns" were usually wood-frame structures on stone or concrete foundations, and had heavily built-up mud walls interlaced with a wood or bamboo lattice as an integral part of the framing. Roofs were heavily built-up of mud carried on a similar lattice between heavy wood roof trusses and were generally covered with tile. The interior was finished with wood lath and plaster, or was wood sheathed, while the exterior was cement coated and sometimes partly aproned with a brick veneer wall (Figure 2, and Photos 12 and 13).

d. Factories. Small factories were either one or two stories in height with no basement, were long wood-constructed buildings and had roofs covered with low-pitched tile, sheet metal or corrugated iron, which were carried on wood trusses supported by a timber frame. Floors were earth, concrete on fill, or raised boards on light joists, depending on the nature of occupancy. Column and truss spacing was usually 6 feet, and building frontages averaged 24 feet. This type of structure had its overhanging eaves removed along street fronts as a protection against fire spread. Building fronts were finished with some noncombustible material such as corrugated iron, plaster or brick. Larger industrial buildings of Aomori ranged between 8,000 and 12,000 square feet in ground floor area and were usually one story high. Structure framing was either of heavy timber, or steel and timber combined (Photos 14 and 15). Exterior walls were of wood, of corrugated iron or of glass set in metal frames on brick or concrete apron walls (Figure 3, and Photos 16 and 17). Floors were finished with concrete, or were unfinished earth. Pitched roofs were covered with sheet metal, corrugated iron, and sometimes wood shingle on boards supported by timber trusses or light steel trusses carried on the supporting frame. Flat roofs were rare because of the heavy snow loading. The use of corrugated asbestos-cement roofing and siding, common elsewhere throughout Japan, was rare in Aomori because of the abundance of lumber. Moreover, brick was not commonly used, unless it was required in specialized industrial buildings or occupancies, such as dry kilns or attached boiler houses. Furthermore, load-bearing brick-wall structures were extremely uncommon.

e. Warehouses. Storage warehouses were of two general types: one was a metal-frame and metal-clad shed-type structure; and the other was a reinforced-concrete multi-story structure. Warehouses were of 5,000 to 10,000 square feet ground floor area, the highest being five stories tall. Concrete slab roofs and slab floors were 4 and 6 inches thick respectively. Exterior walls were either unfinished brick panel or concrete block walls.

f. Public buildings. Except for some wood-constructed public schools, public buildings were similar in structural design to fire-resistive warehouses, except that the concrete slab floors were generally 4 inches thick. The average height of such public buildings was two stories, and none was higher than four stories (Photos 18 and 19).

6. *Fire vulnerability.* The city of Aomori was highly vulnerable to fire, due primarily to densely built-up and congested areas of light, fast-burning, combustible construction. In heavily congested sections in the center of the city, wooden-frame buildings were notably pre-

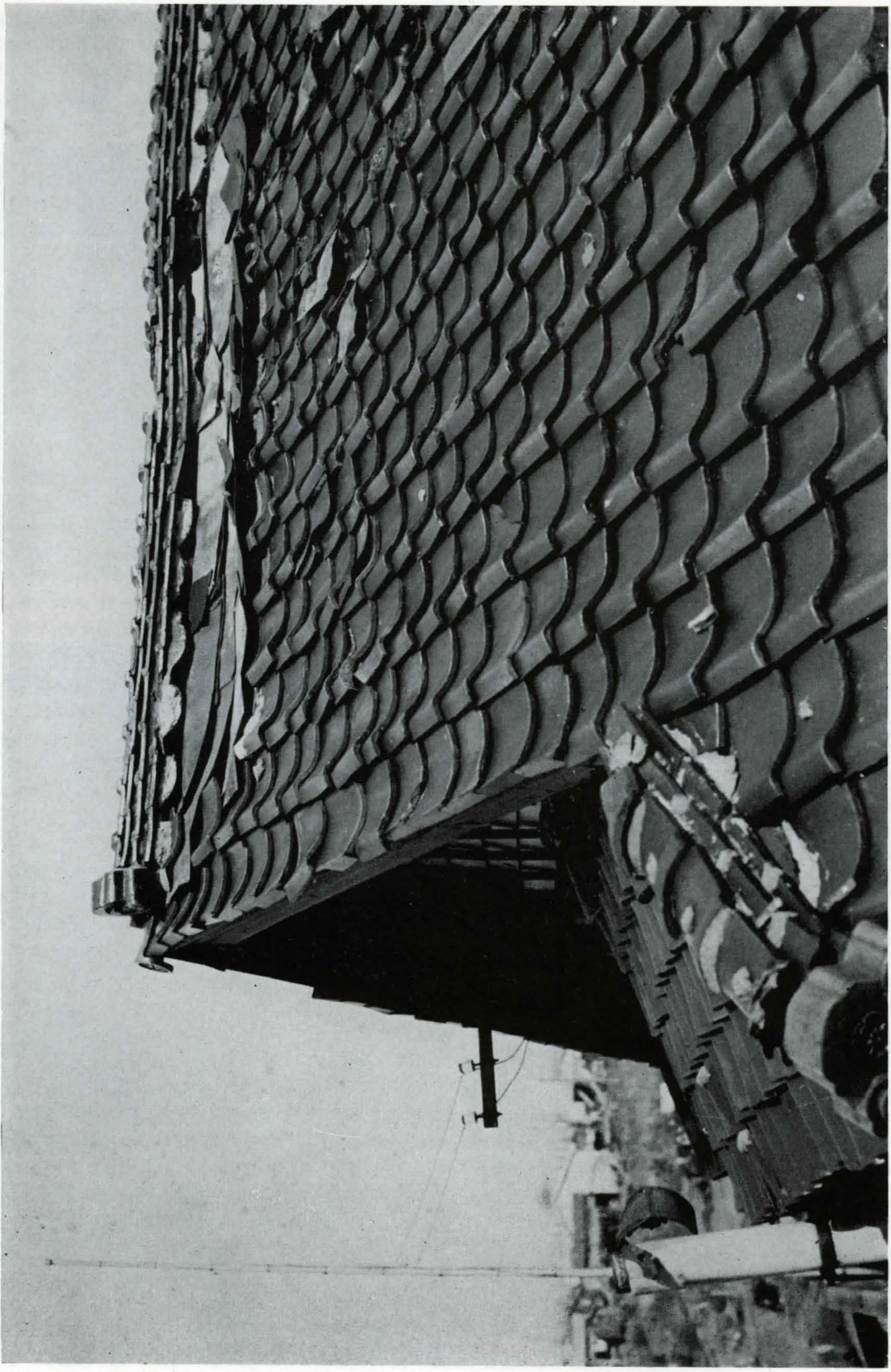
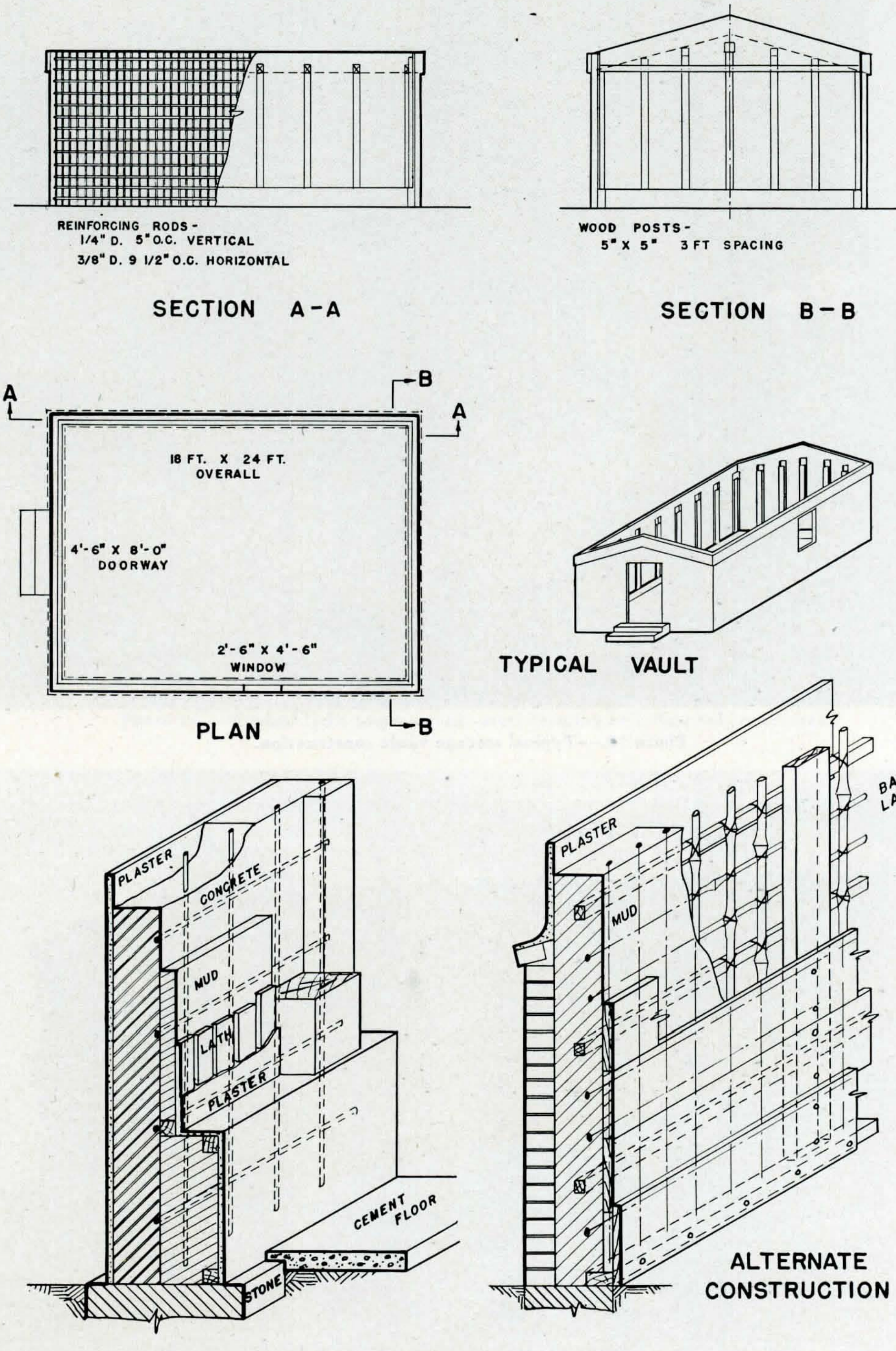


Photo 11.—Typical tile roof of dwelling.



JAPANESE STORAGE VAULTS

U.S. STRATEGIC BOMB. SURVEY
AREA FIRE DAMAGE STUDY
AOMORI, JAPAN
FIGURE 2

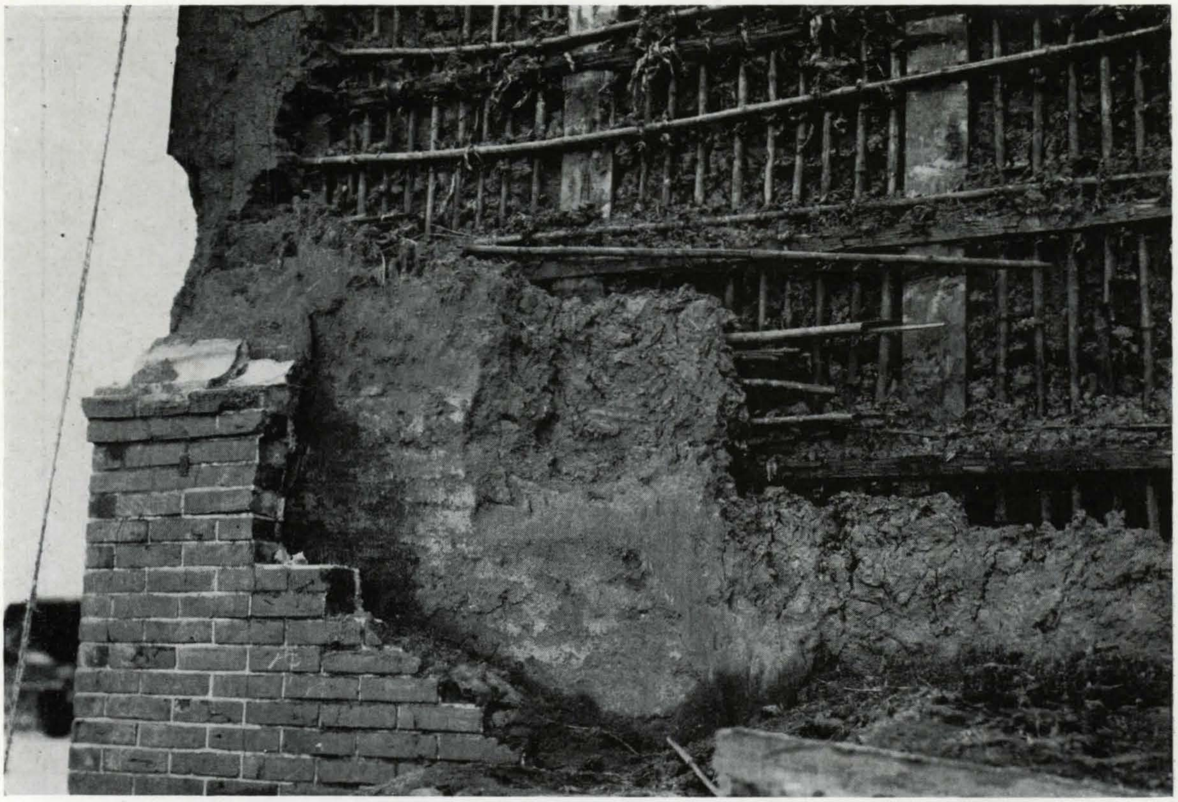


Photo 12.--Typical storage vault construction.

Photo 13.—Detail of storage vault wall construction.

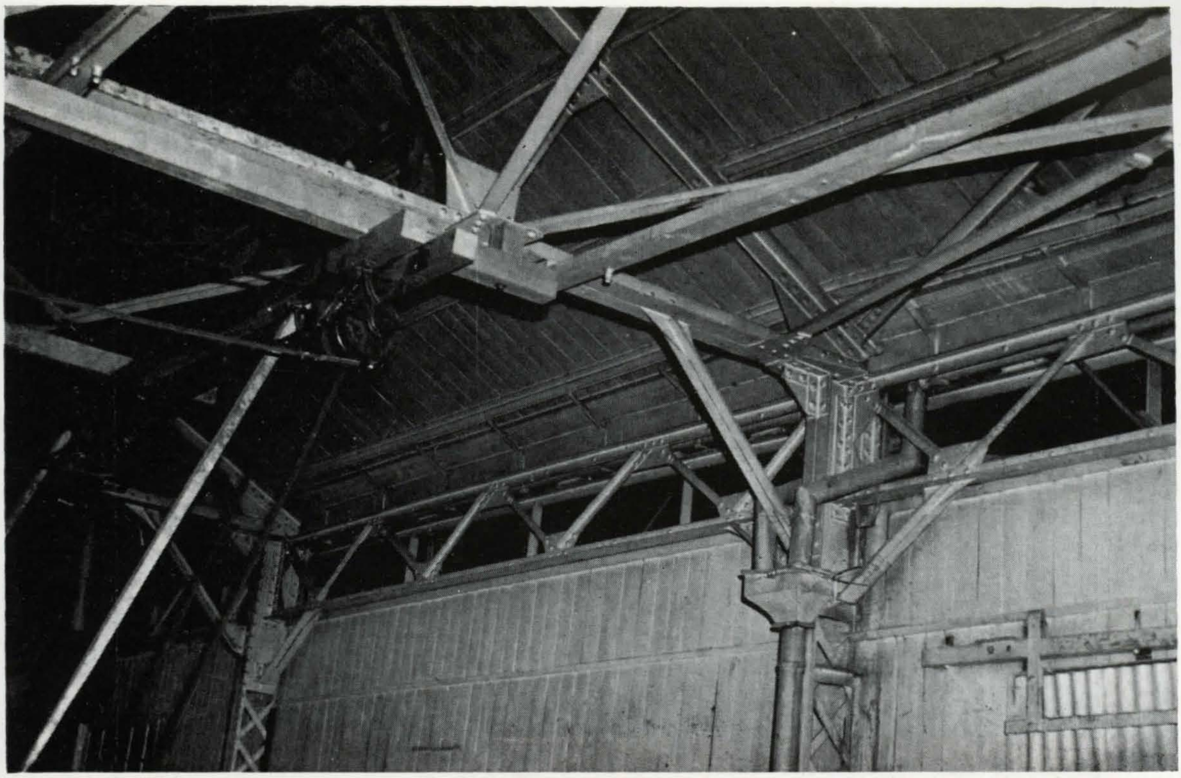


Photo 14.—Typical light unprotected steel framing of industrial structures.

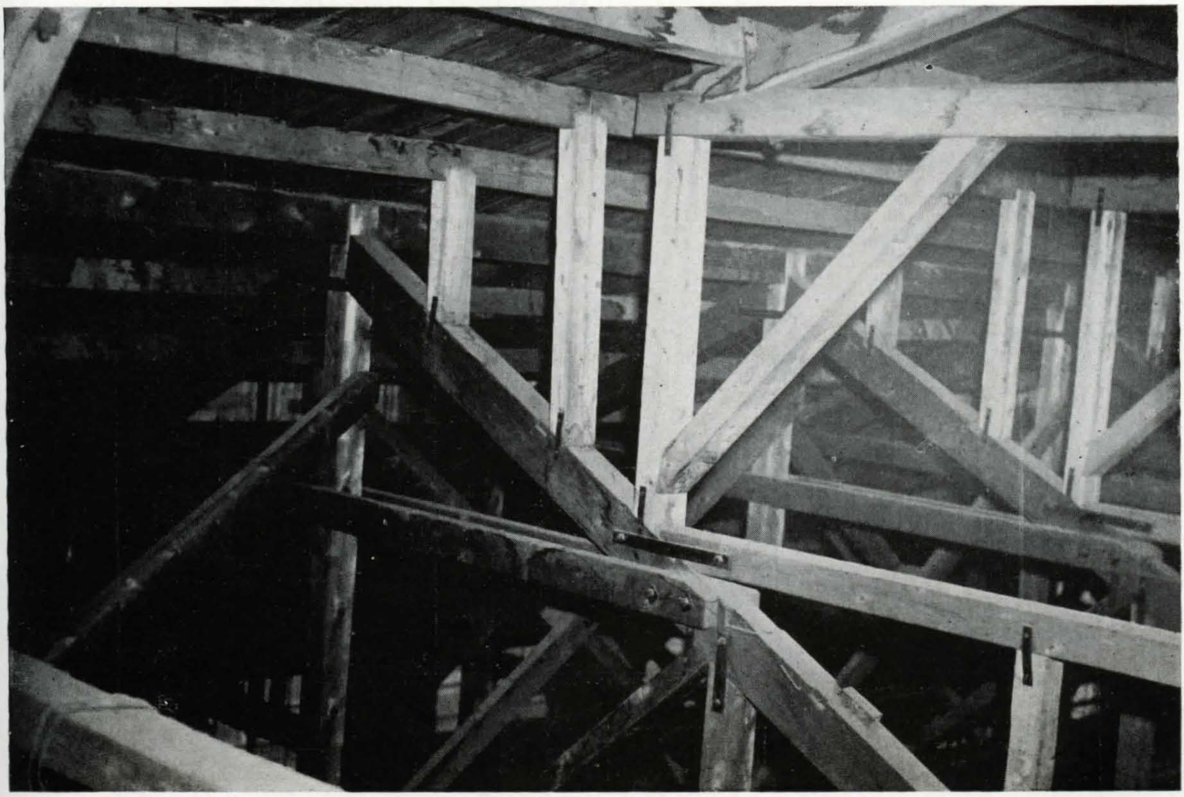
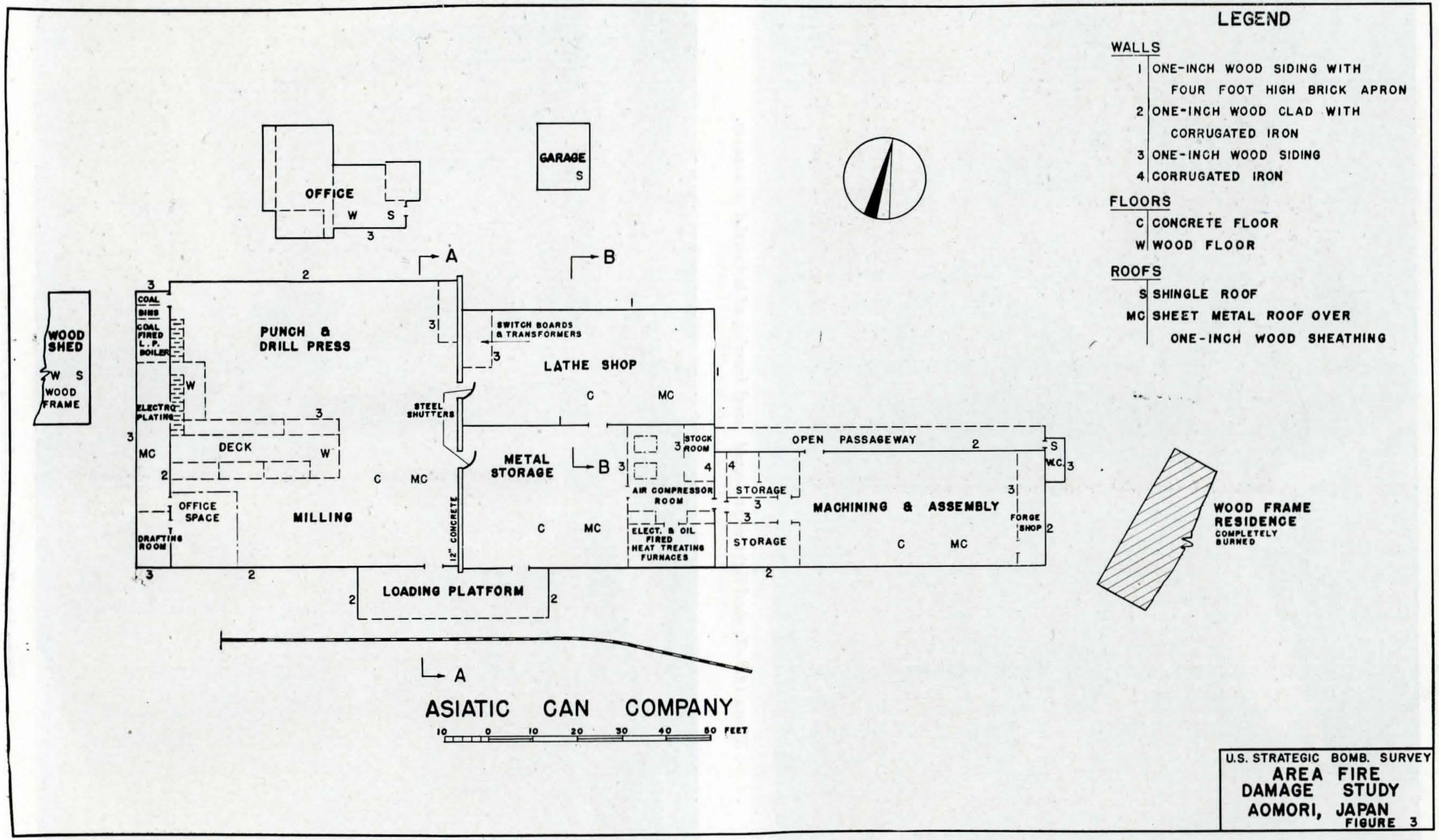


Photo 15.—Typical timber framing in industrial structures.



ASIATIC CAN COMPANY

U.S. STRATEGIC BOMB. SURVEY
AREA FIRE DAMAGE STUDY
AOMORI, JAPAN
FIGURE 3

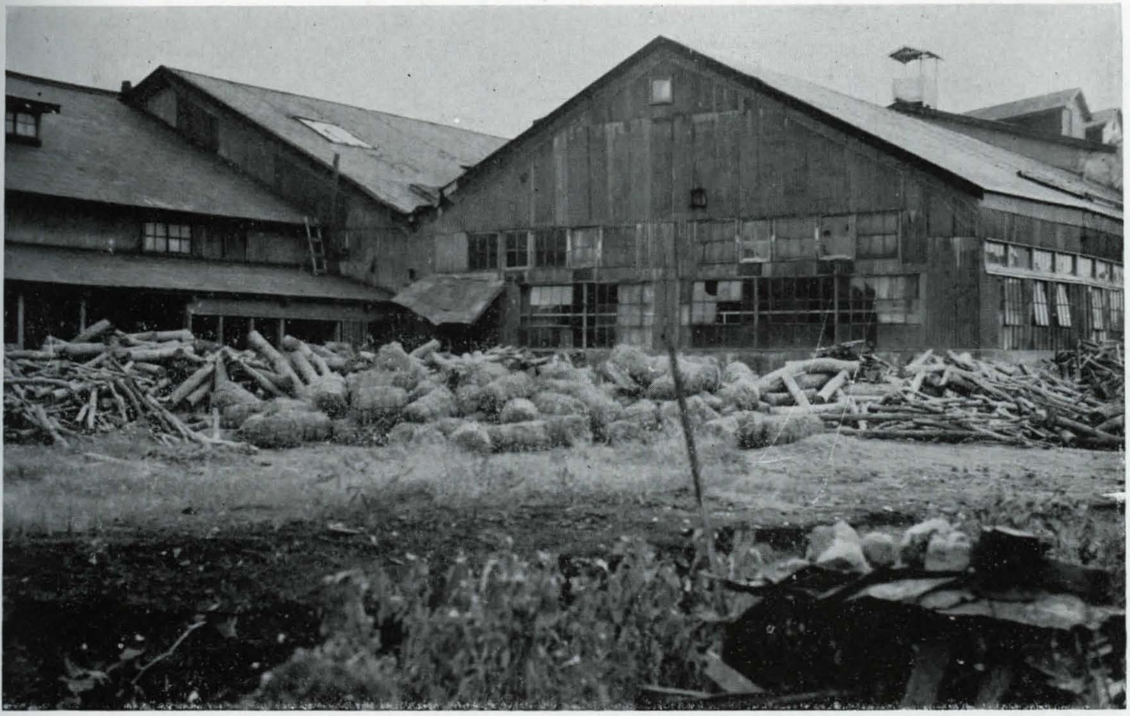


Photo 16. — Corrugated-iron, glass in metal frame exterior wall. Note non-combustible apron wall.

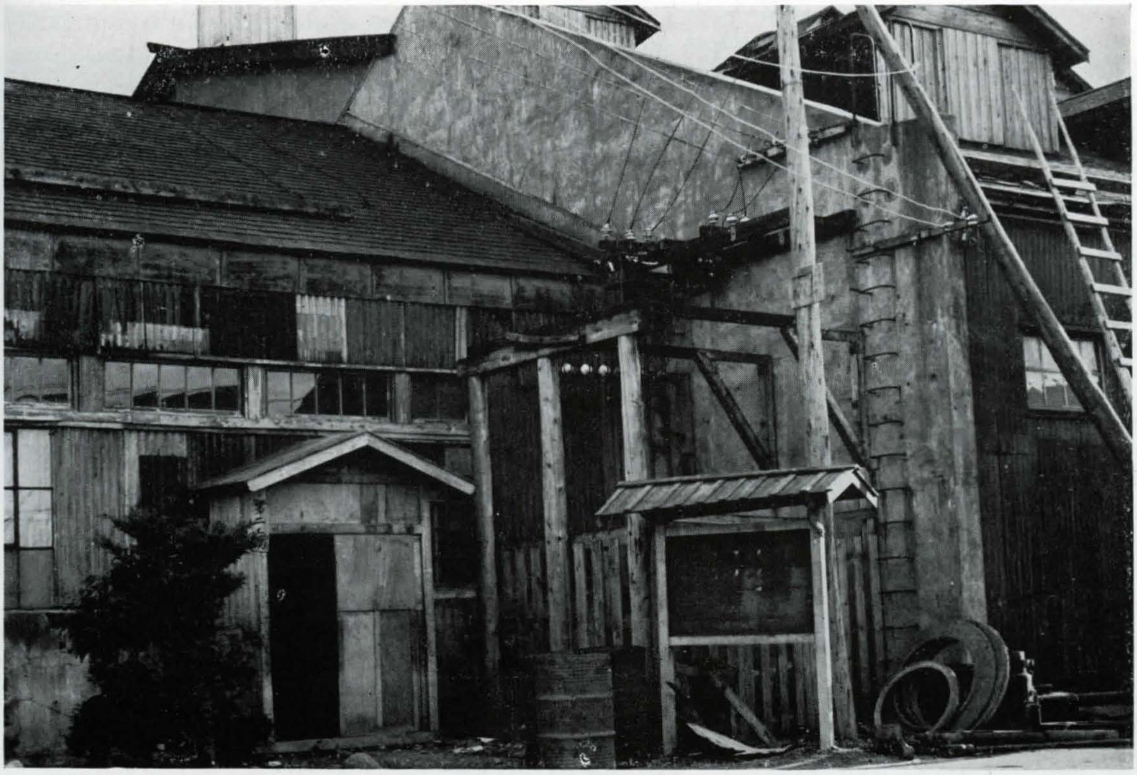


Photo 17. — Mixed construction of exterior wall. Note part fire wall of concrete with parapet.

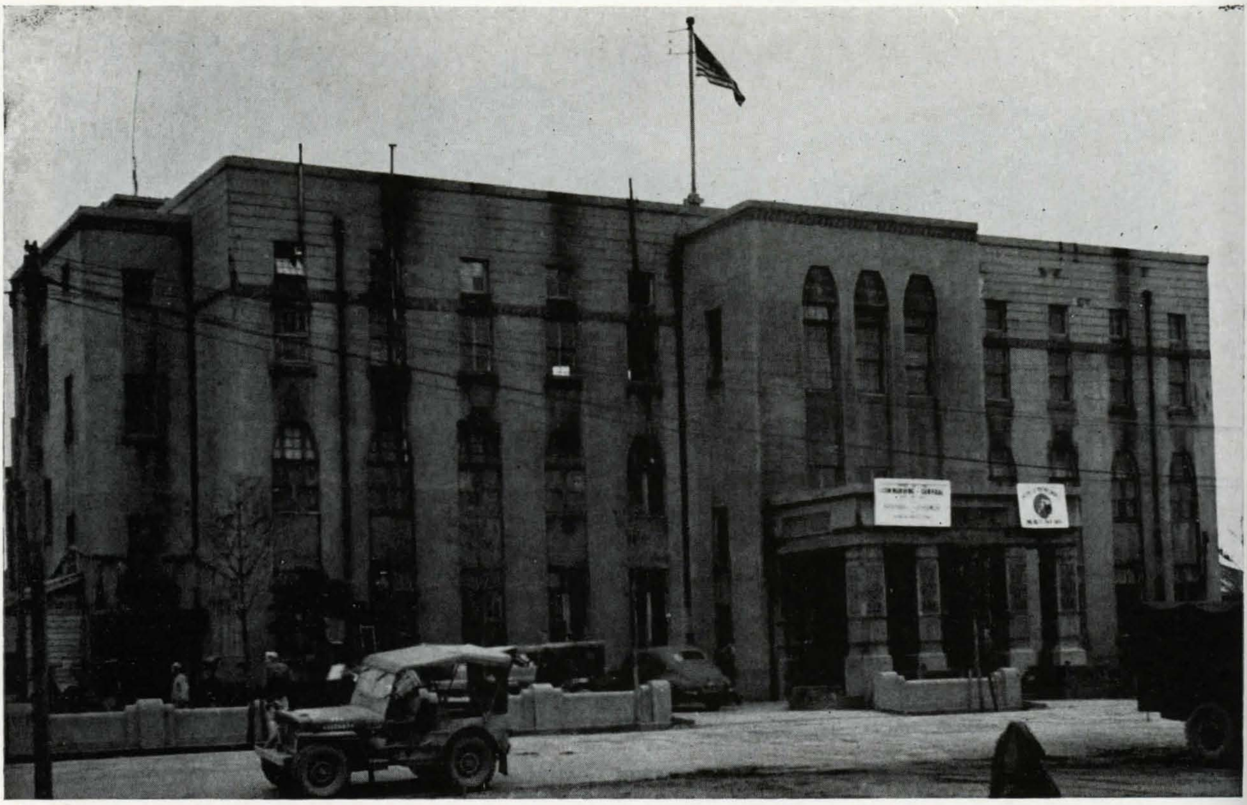


Photo 18. — Aomori customhouse. Typical fire-resistive public building.

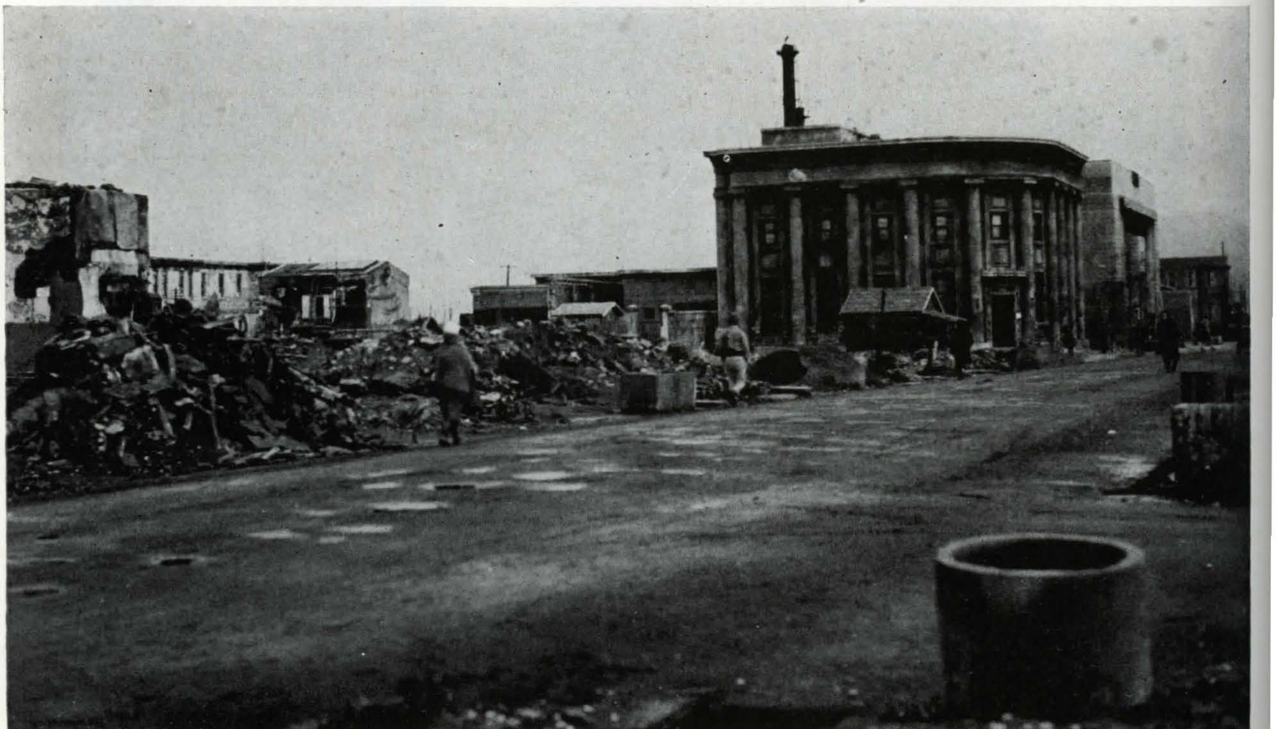


Photo 19. — Reinforced-concrete bank building. Note cistern right foreground.

dominant. These buildings were contiguous along street fronts, and their back-yard areas were well covered with wooden sheds and dwelling attachments. City blocks were separated by streets, the widest about 36 feet, measured building front to building front. Most of the typical streets, however, were narrow and in the range from 18 to 24 feet. Although individual, wooden-frame structures were in themselves extremely susceptible to incendiary-bomb action and subsequent fire damage because of their light, combustible construction, the entire target area was made further susceptible to the effects of mass incendiary attack by the high degree of congestion and building ground occupancy.

V. Weapon Data

1. *Description of bomb.* The weapon used against Aomori was the recently developed M74 incendiary bomb. This bomb commonly known as the 10-pound M74 weighs 8.4 pounds. It is 2.87 inches in diameter and 19.15 inches long. The incendiary charge is 2.8 pounds of PT–1 mixture consisting of a thickened magnesium-gasoline paste. The main ejection charge consists of 0.11 ounce of magnesium powder and 0.07 ounce of black powder. In addition, there is a small chemical container, located immediately behind the nose fuze cup, which is filled with white phosphorous to insure ignition of the charge and to produce smoke to cause anti-personnel effects and confusion. The bomb, like the M69, has a hexagonal, sheet-steel, leak-proof case with a nose cup housing the fuze. It has a telescopic tail which is extended into the air stream under spring pressure when the bomb is released from the cluster. An all-ways action fuze screws into the nose of the bomb, consisting essentially of a steel head, an arming-pin retainer, a steel striker pin, and safety pin, a zinc-alloy die-cast striker, sleeve, a fuze casing, an arming pin M26 percussion primer, a cavity in case filled with one gram of black powder and a zinc booster cup filled with three grams of propellant powder.

2. *Method of carrying.* The bombs are carried in the E48 cluster, with the M23 cluster adapter, in 525-pound clusters, capable of being aimed. When a cluster is released, the arming wires are withdrawn and the two fuzes arm. Upon the expiration of the time setting (the clusters used on Aomori were set to open at 5,000 feet above ground), the short-delay cluster fuze operates to set off the boosters and primacord which is channeled to the fin-retaining cup. The cone is blown off by the primacord detonation, thereby releasing the buckle and retaining straps, and the cluster opens. Upon failure of the short-delay fuze to function, the long-delay fuze operates two seconds later by detonating the primacord extending the length of the cluster, thus shearing the steel straps and releasing the bombs.

3. *Method of functioning.* When the bomb strikes, the M142 fuze striker ignites the primer which sets off the booster and main ejection charge. This action activates the auxiliary ejection-ignition charge; expanding gases rupture the ejection dome at the scored section which breaks and forces the white phosphorous-filled cup and tail assembly out of the bomb casing (Figure 4); and the magnesium and white phosphorous thereupon ignite the ejected filling. This entire action takes place within a space of eight feet from the bomb's point of impact. The bomb was designed so that it would pierce the roofs of the flimsily constructed Japanese dwellings, and explode below the ceiling in such a way that most of the gel would be deposited on the underside of the ceiling where it would be difficult to reach in order to extinguish the ensuing fire. Thirty-eight thousand BTU's of heat are liberated by this bomb, including the heat produced by burning of the white phosphorous.

VI. Attack Data

1. Mission 298, the object of which was to accomplish an over-all incendiary attack on the city of Aomori, was assigned to the 58th Wing of the XXI Bomber Command, Twentieth AF. The two groups of the Wing which were to accomplish this mission were staged at Iwo Jima so that a greater weight of munitions could be carried to the target.

2. The weight of airborne bombs was 583.5 tons of which 546.5 tons were released over Aomori. The intervalometer setting was 50 feet. It is estimated that 2,082 E48 clusters containing a total of 79,116 10-pound M74 incendiary bombs were dropped on the target.

3. The primary target (Aomori) was bombed by 61 B29's between 2301 and 0012 hours, local time, 28-29 July 1945, from 10,000 to 16,000 feet. The axis of attack varied between 77° and 110°. Weather was reported as 5/10-10/10 undercast which cleared up over the target as the attack progressed because of the heat of the fires (Table 1).

4. *Defensive action of the enemy.* Mission Report 298 states that seven aircraft reported heavy-caliber flak over the target, which was meager and inaccurate, and consequently ineffective, and there was no flak upon withdrawal. One ineffective searchlight was also reported. Red and white bursts coming from three small surface craft in the harbor were reported by the crew of one plane.

VII. Defense Against Air Attack

1. *Civilian.*

a. Fire department. As was standard throughout Japan, the Aomori fire department was under the direction of the chief of police of the Prefecture. Personnel of the department consisted of 1,000 men, 150 of whom were full-time firemen, and the remainder served as volunteers assigned to that task by the government as an extra war duty. Prior to the attack there were three large and four small fire stations. The fire apparatus, without exception, was in poor condition and obviously poorly maintained (Photos 20 and 21), and, judging from the results of a demonstration staged for the survey team, it was apparent that the efficiency of the fire department as a well trained and disciplined unit was far below American or European standards.

b. Water Supply. The Aomori waterworks was municipally owned and served approximately 80 percent of the population. The system was of the gravity type with its intake on the Yokouchi River at a point eight miles south of the city in the Oza district. The dam was approximately 150 feet above the mean elevation of the center of the city, resulting in a static pressure of about 65 pounds per square inch. A 24-inch steel pipe carried the water from the dam to the purification plant, and a 20-inch steel pipe carried it from there to the city. The principal arterial mains in the city were 12-inch steel pipes. There were 13,981 private service connections to the distribution system which consisted principally of four-, six-, and eight-inch mains.

c. Hydrants. There were no above-ground hydrants in Aomori, but as is customary in some Asiatic and European cities, the connections for the portable hydrants were located in the streets below the surface of the roadway (Photos 22 and 23). The portable hydrant or standpipe hooked on to the underground outlet which was normally kept shut by means of a ball valve, two inches in diameter (Photo 22). After the hydrant had been securely attached to the outlet, a valve stem, operated by a hand wheel forced the ball downward off its seat, thus permitting the water to rise and flow out of either one or both of the 2½-inch outlets which were individually controlled by hand-operated valves (Photo 23).

d. Civilian defense organization. In accordance with the traditional "face-saving" policy, the Japanese official report (Appendix A) indicates that the civilian-defense units performed heroically and well. Interrogation of a number of city officials and ordinary citizens revealed, however, that there was very little planned civilian defense such as the United States or Europe had. In so far as the facilities were concerned, the block associations had to provide above-ground cisterns, hand-drawn pumping equipment and hose carts (Photo 24).

TABLE 1.—ATTACK DATA CHART

Primary target	Air Force	Date of attack	A/C dispatched	A/C over target	Bombs, airborne tons	Tons bombs dropped on primary target	Altitude of release	Intervalometer setting	Time over target (local time)	Axis of attack	Wind	Visibility	Method of aiming
							Feet						
Aomori, Japan	20th	28-29 Jul 45.	65 B29's	61	583.5	546.5	10,000 to 16,000	50 ft.	2301 to 0012	77° to 110°	Calm	5/10 to 10/10	37 Visual 24 Radar

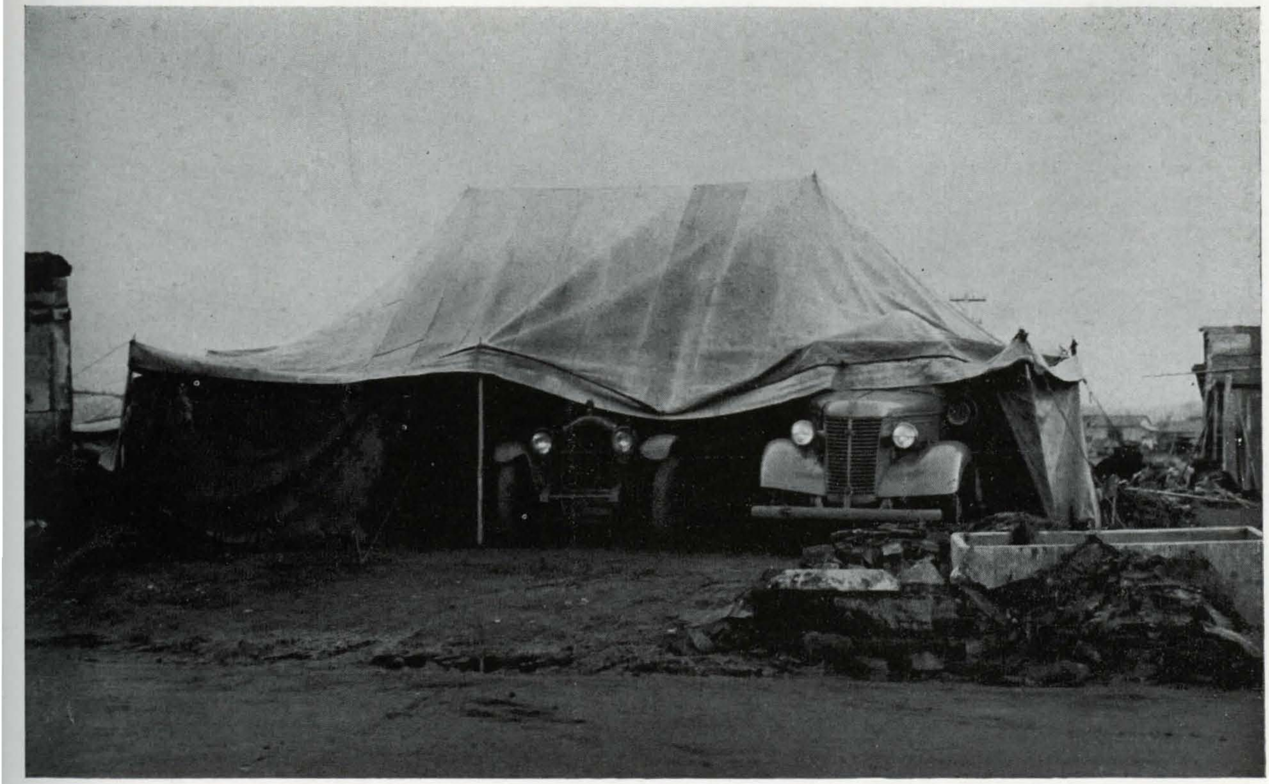


Photo 20.—Temporary "fire station."

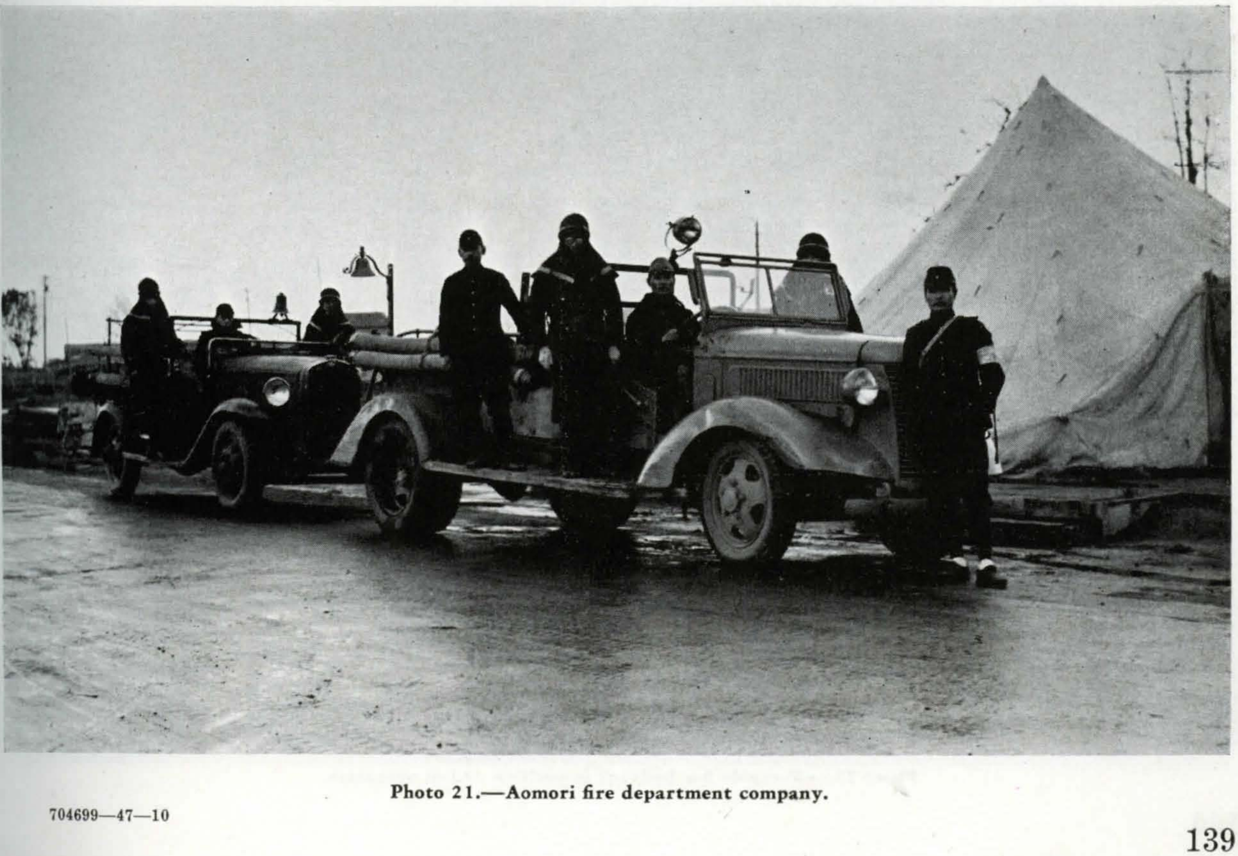


Photo 21.—Aomori fire department company.

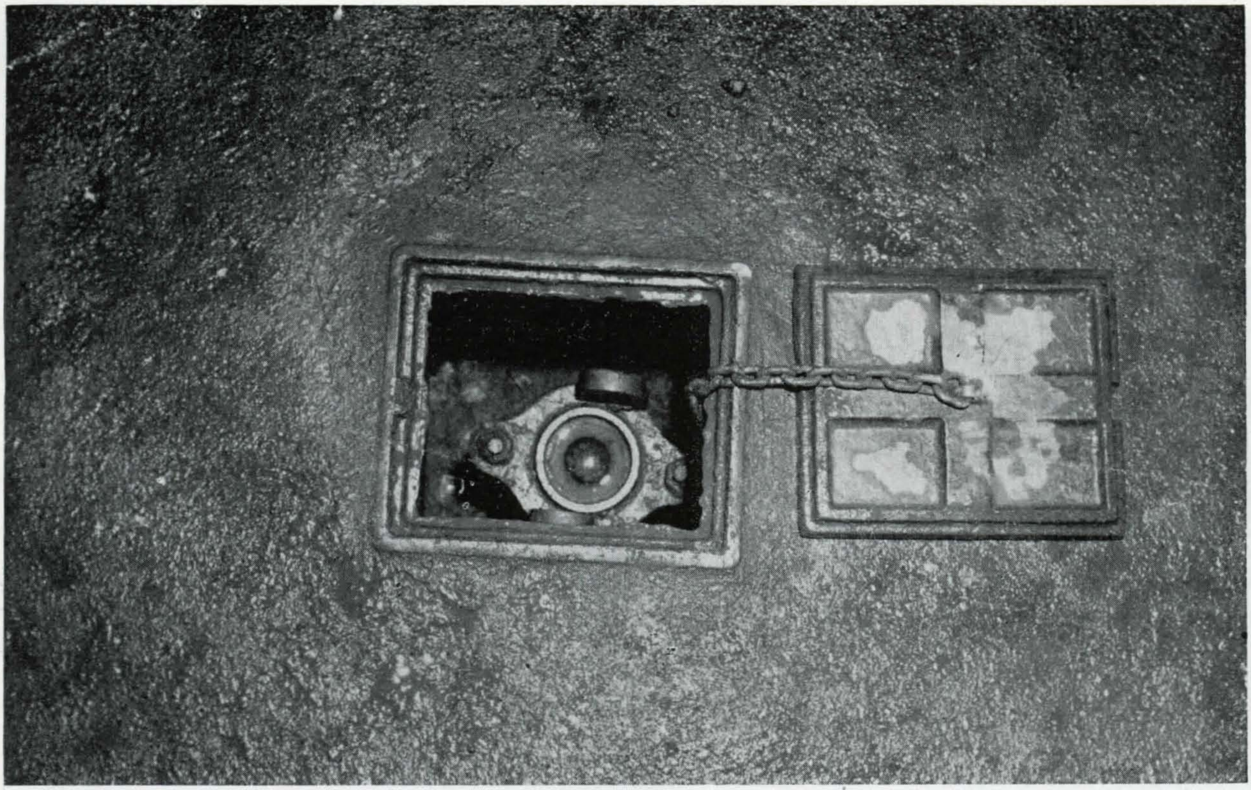


Photo 22.—Subsurface fire hydrant outlet.

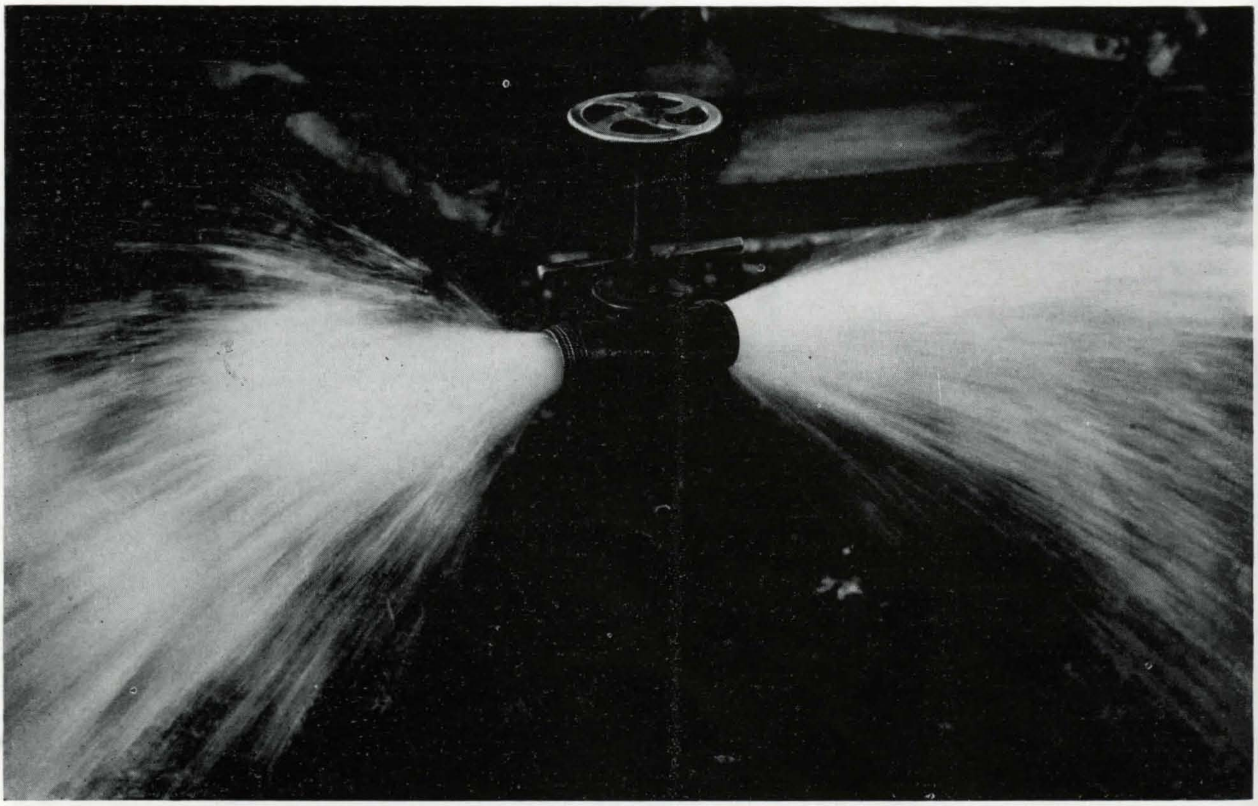


Photo 23.—Portable fire hydrant in position and in operation.

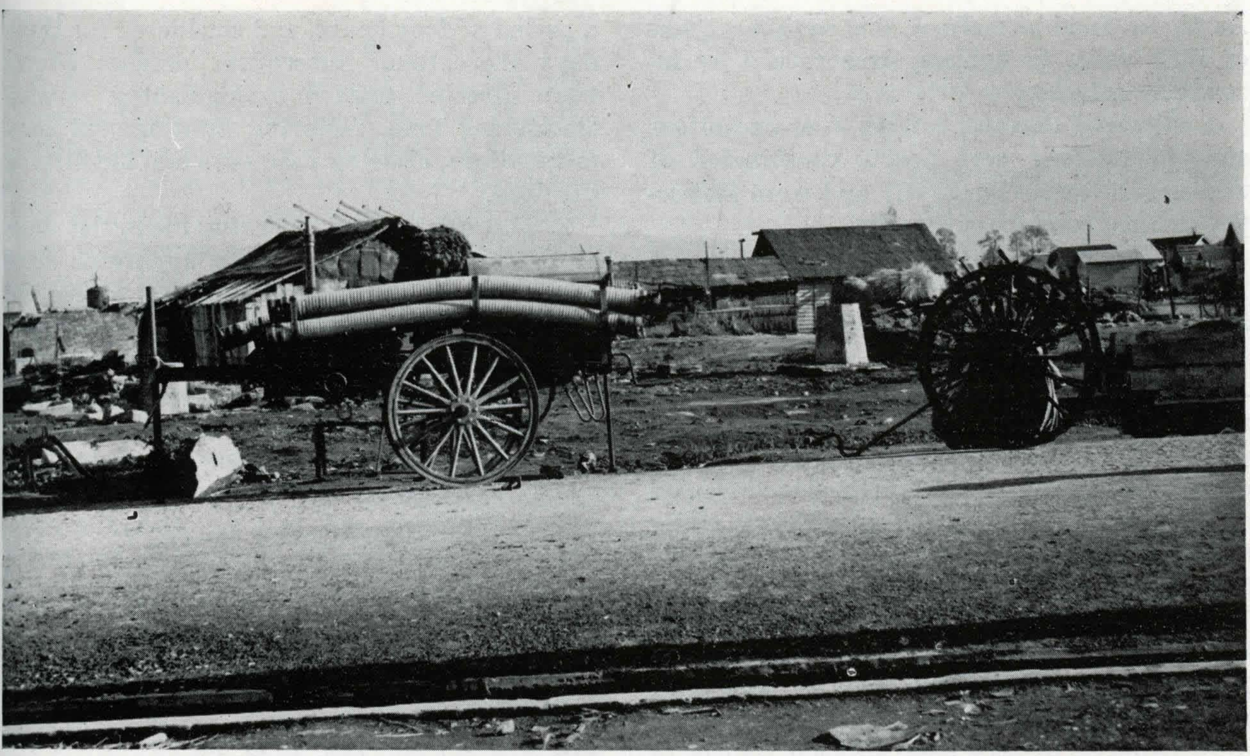


Photo 24. — Hand-drawn hose cart.

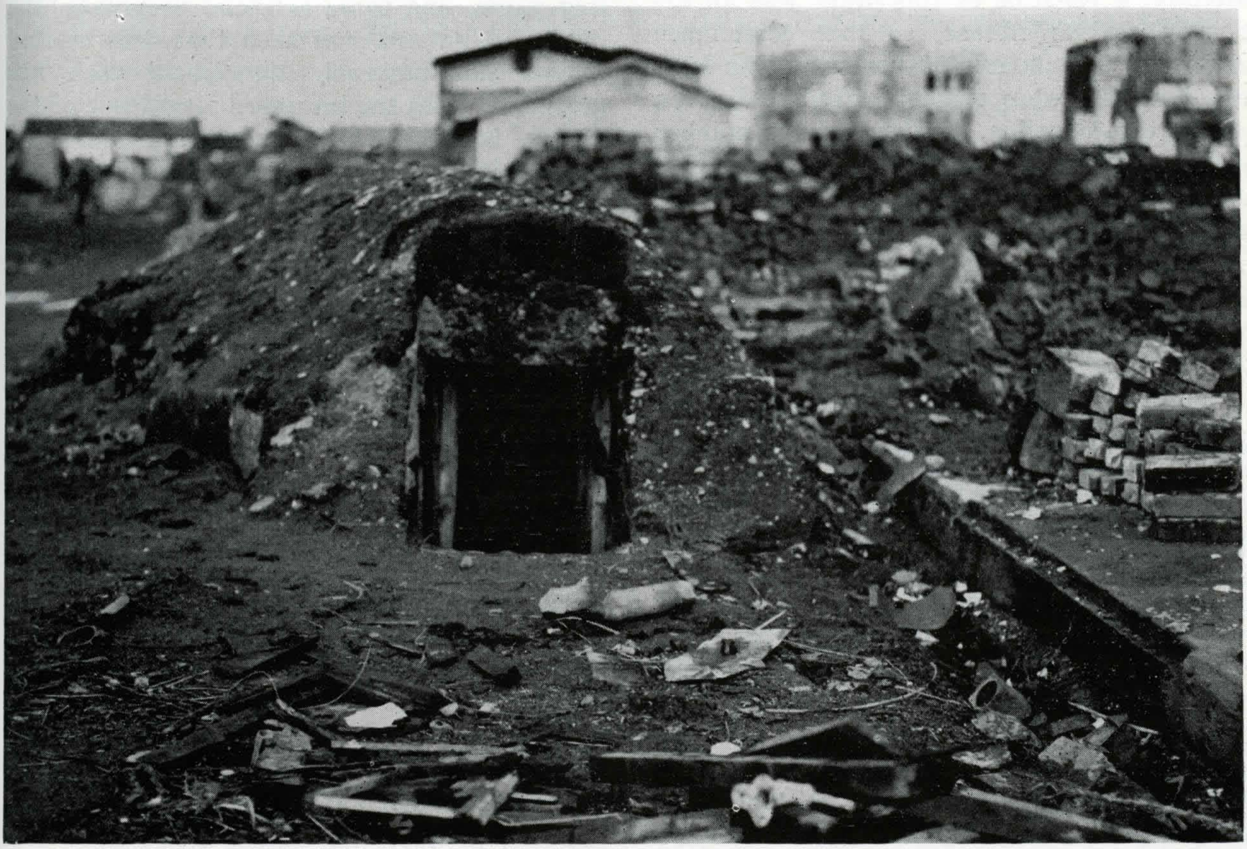


Photo 25. — Earth air-raid shelter.

As far as could be learned, this equipment was of little value in fighting fires caused by incendiary attacks.

e. Air-Raid Shelters. With few exceptions air-raid shelters were poorly constructed of timber and earth (Photo 25) and were ineffective against incendiary attack.

2. *Military*

a. Antiaircraft battery location. An antiaircraft battery was located directly west of Aomori on a site adjacent to the ferry slips. At the time of the survey, this area was visited and all that was found was the remains of the gun positions and observation posts. The site did not impress one as being either well located or properly laid out, the gun positions being close together and not concealed from air observation.

3. *Psychological.* On 27 July 1945, the day before the attack, leaflets were dropped on Aomori warning the people that an air attack against their city was imminent. The people were required to turn over all such leaflets to the prefectural police without delay, and, apparently, a violation of this order was an extremely serious offense, so that compliance therewith was almost 100 percent. The leaflets, however, were evidently read and given serious consideration, because a large number of the population, particularly women, children and old people, took what possessions they could carry and sought refuge in the woods.

VIII. The Fire

1. *General.* The incendiary-bomb attack over Aomori lasted for a period of 1 hour and 11 minutes. At its onset, various defense organizations attempted to fight the scattered incipient-stage fires, but, with the increasing magnitude of the attack and the subsequent spread of the areas involved in fire, this initial fire-fighting effort was soon abandoned, so that, after the first 20 minutes, there was no further organized attempt to combat the spread of flames or to extinguish fires, except on the part of a few groups of persons in the suburbs. The efforts of all defense agencies were then directed toward evacuation of the populace from the city. Meanwhile, the initial-stage fires had merged into a fire of conflagration proportions, and the entire area burned intensely for a period of four hours, and smoldered for three days thereafter. Subsequent defense efforts were directed toward extinguishing isolated smoldering fires, restoring lighting and communications, clearing roadways and identifying the dead.

2. *Fire department.* During the initial stage of the attack, fire department apparatus were dispatched to predetermined areas within the city where firemen, with the aid of civilian-defense organizations and reserve fire organizations, fought incipient-stage fires, until forced to withdraw from the area because of increasing personal danger and lack of water. In many instances, fire apparatus were abandoned in burning areas, and, in some cases, the withdrawal of equipment was impossible due to the impassability of roads because of fire-softened asphalt paving.

3. *Development of fire.* At the start of the attack, a great number of dispersed individual incipient fires was started throughout the city. Although the city was divided into natural fire divisions by a canal, a river, railway marshalling yards, and three artificial firebreaks, the bomb-fall pattern was such that fires started almost simultaneously throughout each fire division. With the increased magnitude of the attack, individual fires in each fire division merged into one big conflagration without regard to natural or artificial firebreaks. There was no indication of the development of a "fire storm," although a column of smoke was observed to have risen to the height of 20,000 feet over the city. The period of intense fire was estimated at four hours, following which the fire subsided rapidly, and, by early morning, the area was sufficiently cooled to allow rescue workers and clean-up details to enter. Except for some isolated fires, the greater part of the area lay a smoldering ruin.

4. *Communications.* Communication networks among operating defense agencies in the burning area and between those agencies and their respective headquarters were interrupted shortly after the initial attack, and soon thereafter became inoperative for the rest of the attack period. Twenty-four hours later, only the more important government buildings which remained standing were provided with emergency telephones. Information was re-

layed to the homeless people by means of cruising radio cars and posters on bulletin boards.

5. *Power.* Although neither of the two power substations was involved in the fire, the distribution network was extensively damaged in many places. Lighting was restored two days following the attack on a very limited scale, with temporary lines running to the few remaining government buildings.

6. *Evacuation.* Evacuation of the populace was directed by the prefectural police according to a prearranged plan. A greater part of the population had already moved to the hills outside the city as a consequence of the leaflet warning dropped the day before, but, on the day of the attack, some had returned to the city to pick up food rations. There is, however, no estimate of how many persons had evacuated the city prior to the attack, nor of how many had returned that day. Interviews revealed that the police experienced difficulty in evacuating the aged, but were able to use artificial firebreaks to good advantage as avenues of escape.

7. *Deaths in shelters.* The Japanese reported finding a number of unburned bodies in air-raid shelters, death having been caused by either asphyxiation or the inhalation of hot gases and consequent searing of the lungs.

IX. Damage

1. *General.* It was estimated that 88 percent of the city of Aomori was destroyed as a result of the attack of 28-29 July 1945. The following table shows the areas of the city and its suburbs destroyed with reference to built-upness (Photo 26):

Area Damage Table

Built-upness	Area subject to damage (acres)	Area damaged (acres)	Percent of area damaged
City of Aomori	753	668	88
Densely built	488	464	95
Sparsely built	265	204	77
Suburban Aomori	303	20	6.5
Densely built	2	2	100
Sparsely built	301	18	6
Total Aomori	1056	688	65
Densely built	490	466	95
Sparsely built	566	222	39

a. Damage to major industries in the area based upon Japanese figures is tabulated as follows:

Industrial losses

Industry	Totally destroyed (in burned area)	Undamaged (outside burned area)
Lumber mills	3 mills.	6 mills.
Lumber companies	2 plants.	3 plants.
Warehouses (general)	19 buildings.	5 buildings.
Shipbuilding yards	1 site.	2 sites.
Canneries	1 factory.	2 factories.
Fishing [1]	102 boats (38 sunk, balance damaged beyond repair).	3 boats.
Transportation, rail rolling stock	61 cars.	Unknown.
Water [2]	25 ships.	Unknown.

[1] Does not include transport and cargo ships.

[2] Does not include fishing vessels.

b. The following figures are based on the Japanese record of casualties incurred as a result of the attack:

Casualties:

	Persons
Total casualties	1,016
Killed	728
Seriously wounded	40
Injured	240
Missing	8

c. Losses of the fire department, based on Japanese figures, are tabulated as follows:

Fire department losses

	Totally destroyed	Seriously damaged (beyond repair)
Fire stations	3 buildings.	4 buildings.
Fire department apparatus	19 vehicles.	12 vehicles.

d. Japanese figures note in addition that 11,330 dwellings were destroyed, rendering 17,843 families homeless.

2. *Analysis of damage*

a. Bomb density. The probable average bomb density in the central portion of the target has been estimated as 272 tons per square mile. This estimate is based on the reported delivered bomb load on the target area and assumes that 90 percent of the bombs fell within a limit as shown in Figure 1 as "Probable Limit of Bomb Fall." This limit of bomb fall is an oval which encloses all areas of damage within the target area and is based on ground observations at the target site. If it is assumed that a normal (Gaussian) distribution of bombs was achieved along any diameter on this oval, then

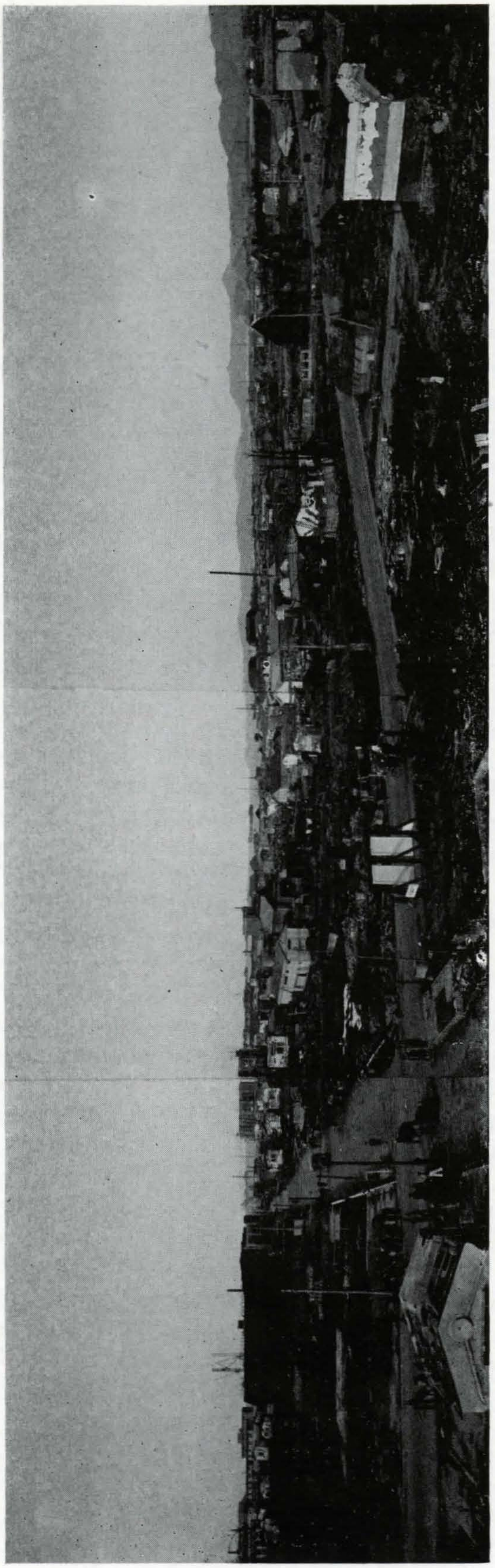


Photo 26.—General view of fire damage area.

it is calculated that 46 percent of the total reported delivered bomb load arrived within a central portion of the target area measured as 25 percent of the total area of oval. This calculation results in a probable bomb density of 251 tons in 0.92 square mile of area, or 272 tons per square mile.

b. Appraisal of bomb density. The twentieth AF has reported an average CPE (circular probable error) of 4,000 feet radius for night radar bombing with good target identification. This CPE determination was based on aerial photograph interpretation of several target areas, and is defined as a circular area of measured radius in which 50 percent of the bombs dropped are expected to arrive. The estimated maximum bomb density of 272 tons per square mile corresponds favorably to a CPE of 3,400 feet, which is not at great variance with bombing experience.

c. Damage characteristics. The central portion of the target area was well burned out, as shown in the damage table. Of the area that was heavily built up, 95 percent was completely consumed. The thoroughness of fire damage was likewise noticeable in the sparsely built-up areas of the city, particularly in the suburbs. Combustible structures within the perimeter were completely destroyed in the burned area, or were intact, if outside the perimeter of the consumed area. There were no cases noted of partly burned combustible structures. Noncombustible structures sustained structural damage in direct ratio to the combustibility of their contents. Fire damage to these structures ranged from light superficial damage to complete structural damage, and, in all cases observed, this damage was caused by burning of contents. Noncombustible structures sustained only light superficial damage due to exposure fires, when the contents of such structures was likewise noncombustible. Fire-resistive structures sustained only minor damage from contents fires (started as a result of exposure fires transmitted through unprotected openings) or from exposure fires. The typical Japanese treasure-house type of construction stood up well in the fire. Any damage resulting therefrom was generally limited to structural roof damage, while the walls remained intact.

d. Efficiency of the attack. An estimated 1.3 acres were damaged for each ton of bombs reported delivered on the target. Relative appraisal of attack efficiency based on this measure of damage area per ton of bombs dropped is beyond the scope of this report. This figure must be compared with other damage figures on a damage area per ton basis.

e. Accuracy of the attack. The aiming point in the target area is synonomous with the Mean Point of Impact, shown on Figure 1. The center point of the probable limit of bomb fall differs by only 2,300 feet distance from the Mean Point of Impact. The attack was reasonably accurate, therefore, considering the conditions —such as altitude and night radar with fair-to-good target identification—under which it was carried out.

f. Effectiveness of the Bomb. The M74 is considered a highly effective bomb, based on the results achieved against this particular target. Although the success of the attack is evaluated by the bombing accuracy, the concentration of bombs within the target area, and the vulnerability of the target to fire, it remains a function of the individual bomb to start an incipient-stage fire when striking. According to Japanese accounts of the performance of the bomb in this respect, and in view of the extent of fire damage, the M74 was successful in raising the necessary individual incipient-stage fires in numbers great enough to overwhelm fire-fighting counter-measures.

g. Fire spread:

(1) A study of the perimeter of the fire-damage area reveals that the fire stopped at 61 percent of the total perimeter because there was nothing left to burn, while at the remainder of the perimeter, 39 percent, the fire stopped in sparsely built-up areas because of varying expanses of clear space. Only in the case of one city block, and for a distance of 200 feet, did the fire stop at a 24-foot street in a densely built-up section of the city.

(2) The wind was not a factor in fire spread as it did not exceed seven miles per hour for the period of the attack and for the following six hours.

(3) There was no test of the effectiveness of the firebreaks in stopping fires. Because of the wide bomb-fall pattern over the target area, fires involved both sides of natural firebreaks,

such as river, canals and railroad tracks, and specially constructed firebreaks in the form of widened streets.

h. Bomb penetration. Scant information was gathered regarding bomb penetration owing to the fact that the military had picked up bomb cases, disposed of malfunctions, and otherwise obliterated evidence. Some cases of bomb penetration in soft earth were observed of the order of 8 inches. No cases of bomb perforation were observed in 4-inch concrete roofs.

i. Air bursts. A number of Japanese were interrogated to determine the extent of air bursts. It was learned that there was a considerable number of bursts, most of which occurred at about 5,000 feet elevation.

X. Recuperability

At the time of the survey (4-11 November 1945) there was much building activity and there was every indication that it would continue. Planned construction of permanent-type, frame-dwelling units was being accomplished with unusual rapidity due, for the most part, to the fact that Aomori has easy access to lumber, and because the lumber mill industry was not seriously affected by the attack. Then, too, there was a large number of experienced, industrious workers available.

XI. Conclusions and Recommendations

1. This attack showed that the recently developed M74 incendiary bomb was an effective weapon when used against a combustible target such as Aomori. The results were excellent in that this bomb was apparently adequate in design and function, and the density of bombs was sufficient.

2. The results indicated that the M74 was unsatisfactory against concrete roofs in that none was perforated.

3. Air burst of bombs was observed by several witnesses.

4. Firebreaks were found ineffective because of the wide dispersion of the attack over the city. Firebreaks and the natural breaks such as the canal, the river, and the railroad tracks afforded the people, however, avenues of escape that undoubtedly reduced the number of possible casualties.

5. It had rained during part of the attack, and humidity had been high prior thereto. These climatic conditions apparently had little effect on the intensity of the fire.

6. This attack provided further evidence of the ineffectiveness of fire fighting in a heavy attack, because of the large number of fires that started nearly simultaneously and the rapidity with which they burned completely overwhelmed the local fire department.

7. The people of Aomori had received little or no instructions concerning the basic air-raid precautions. Feeble attempts were made by constructing earth shelters and providing above-ground cisterns and hand-operated pumps. It was evident that prior to receiving notice of the pending air attack through the leaflets dropped by the United States Air Force, the people believed that their city would not be attacked. Unexpected attacks against such cities are valuable particularly insofar as they affect the morale of the people.

8. Earth and timber air-raid shelters were found inadequate in this incendiary attack. Many people who sought refuge in them became casualties through asphyxiation.

9. The densely built-up sections of the target area burned out more completely than the sparsely built-up sections, as shown in the Damage Table. The amount of damage sustained in the densely built-up area (466 acres) was 2.15 times the amount in sparsely built-up areas (222 acres), yet the sparsely built-up area subject to damage was 15 percent larger than the densely built-up area.

APPENDICES

Page

A. Translation of Prefecture Police Report of Raid........................ 148

B. Description of Kawamura Match Factory Fire........................ 152

C. Other Attacks on Aomori Area........................ 154

Appendix A

(Translator's Note. This is a report of the B29 attack on 28 July 1945 as published by the Prefecture Police Department. Copies were distributed to defense units in the area. It includes the results and methods of attack, counter measures by various departments to combat the fire, and a study of their results.)

B29 Attack

The following is a report gathered from documents and telephone information.

1. *Air-raid defense warning*

Date	Time	Area	Type
July:			
28	2115	Aomori Prefecture	Air-raid alert.
28	2210	do	Air-raid warning.
29	0022	do	Raid-over.
29	0033	do	All-clear.
28	2215	Ominato	Air-raid alert.
28	2301	do	Air-raid warning.
28	2317	do	Raid-over.
29	0020	do	All-clear.
28	2215	Hokkaido, Eastern Sea Frontier	Air-raid warning.
29	0020	do	All-clear.
28	2215	Tsugaru Sea Frontier	Air-raid warning.
29	0020	do	All-clear.
28	2130	Hokkaido, Southwest Sea Frontier	Air-raid alert.
28	2350	do	Air-raid warning.
29	0035	do	Raid-over.
29	0045	do	All-clear.

2. *Types and number of planes:* about 70 B29s.

3. *Altitude of Flight:* 4,000 to 6,000 meters.

4. *Enemy planes bomb run.* On 28 July at about 2223 hours, B29s arrived on the target entering the prefecture by way of the Sugaru and Omagne areas, having come north from Ojika Peninsula and Akita Prefecture. Starting at 2330 hours, a formation of three to five planes attack for two hours dropping incendiaries, small can-shaped type bombs and fountain-pen type bombs. The planes levelled off at the southeast leaving by way of Iwate Prefecture toward the open sea.

5. *Bombs*

50,000 jelly, phosphorous and electron, large and small incendiary bombs.

1,000 small "can" bombs.

A few fountain-pen type bombs and star shells.

6. *Weather report:*

Time	Wind direction	Wind velocity	Weather	Atmospheric temperature (cent.)	Humidity
		Meters sec.			*Percent*
2100	NNW.	1.0		19.1	92
2200	Calm	0.0	Rain	19.1	93
2300	Calm	0.5		19.0	94
2400	NNW.	1.8		18.9	95
0100	N.	3.3		18.5	96
0200	N.	2.2		18.4	97
0300	N.	1.2		18.2	97
0400	N.	1.0	Misty	18.3	98
0500	Calm	.0	Misty	18.5	99

7. *Bombed areas.* Aomori (City), Aomori Suguras, Gosho, Gawara, Kozukuri Nanare, and a section under the jurisdiction of the police department.

8. *Damage*

a. See table (recapitulation of damage and losses).

b. Casualties suffered by the principal air-raid defense units:

Dead: Police officials, 5 (whereabouts of 21 unknown; firemen, 1; civilian-defense corps personnel, 4; air-defense observation unit, 6.

Wounded: Police officials, 14 (4 of these seriously); firemen, 2 (seriously); civilian-defense corps personnel, 7.

c. Important buildings destroyed by fire. Aomori Prefectural Office, Aomori Area Law Court and Prosecutor's Office, Aomori Public Office, Aomori Police House, Aomori Water Police Department, Aomori Post Office and local offices, Sendai Railway Bureau, Aomori Control Department, Revenue Office, Normal School, Aomori Middle School, Aomori High School for Women, Aomori City High School for Women, Aomori Hospital used by the Aomori Medical School and nine other government-owned schools.

d. Important factories. Aomori Shipbuilding and Iron Works, Aomori Iron Works (half burned), Tohoku (Northeast) Plywood Company, Inc., Office, Towada Miso and Shoyu Sauce Co., Inc.

9. *Operation of important air-raid defense units*

a. Police department. This department, in addition to planning the preliminary fire-fighting methods, supervised evacuees, dug up the dead, and identified bodies. They also supervised the civilian-defense radio and information sections and prepared propaganda. They gathered and transmitted intelligence reports to the prefecture officials. Six policemen died and 14 were injured during the attack. The police department received high praise from the people because of the heroic manner in which it performed its duties.

b. Civilian-defense corps. At the time of the alarm, there were 350 members of the civilian-defense corps available for duty. They were assisted by 410 members of the Army-Navy Defense Unit. During the early stages of the attack, although they valiantly attempted to fight the fire, the attack continued and fire spread with the result that they could no longer cope with it. Five died and eight were injured. The members of this corps received high praise because of the unselfish manner in which they carried out their tasks.

c. Air-defense observation unit. The headquarters of the Air-Defense Observation unit was in the center of the city, and, even though they were besieged and hindered by the fire attack, Adjutant Shioya and his subordinates consisting of 26 (all of the Women's Corps) maintained communications until the very end, and, finally, when the communications were broken off, the Adjutant had his staff carry the communication equipment in their hands. As soon as they retired to the duty room, the fierce fire raged about them to the extent that they could not move and became panicky. In spite of the fine judgment of the Adjutant, six did not leave the dangerous place. He took charge, but finally died at his post.

d. Military personnel. At dawn on 29 July the Tohoku 93 Unit quartered in Aomori received orders from the Army Headquarters to engage in controlling the remaining fire. After the conflagration, there were 1,000 men from the Tohoku 80 Unit who engaged in cleaning up and opening the roads, restoring communications, and policing the area.

10. *Plans of Action*

a. Policemen and civilian defense. Immediately after the attack, the policemen and firemen received their orders from all of the police departments of Hirosaki, Owani, Itayagi, Gosho Gawara, Namioka, Kuroishi, Kominato, Nobeichi, Kanita, Sambongi, Shichinohe, Kizukuri, and Kanagi.

b. Communication liaison. Communications with police department and the central and relating army units.

Tsugaru area—Shinkimura (about 2.44 miles from Aomori).

Nambu area—Nonai Mura (about 4.88 miles from Aomori). Mr. Chiba, with the aid of 11 men, organized 2 units of 6 men to a section, with 2 of them remaining behind, and was able to contact the Home Ministry, Tohoku Governor General, and Hirosaki General Headquarters by crawling on the ground to get to the railroad telephone.

c. Investigating damage done in the prefecture. The above-mentioned personnel, by using the railroad telephone, were able to communicate to all police stations and report the damage.

d. Gathering evacuees. As the fire damage increased, evacuees were assembled in the following places according to previous plans:

Tokuuchi Mura—4,143 persons; Shinkimura —500 persons; Ona Mura—6,050 persons; Arakawa Mura—6,151 persons; Takada Mura —2,200 persons; Kokouchi Mura—6,500 persons; Tsutsui Mura—3,200 persons; Hamadate Mura—6,717 persons; Harabetsu Mura—3,201 persons; Nonai Mura—740 persons; Okuuchi Mura—200 persons. Total 39,602. Some 67,280 persons remained in Aomori.

e. Medical aid measures. Places of refuge were established in Kami Hospital, Aomori Shinkoren Hospital, Public Hall, Zodo Primary School, Aomori Technical School, and Aomori Medical College. Relief sections were also established in Nonai, Gosho Kawa Hara, and Hirosaki. The Hirosaki Army Hospital, Aomori Army Hospital, Ominato Guard District, Ominato Naval Barracks, and Iwa Headquarters Unit Relief Section also gave aid and administered relief.

f. Opening of roads. Policemen, civilian-defense corps personnel and coal workers units were mobilized to open the roads from Aomori to Shin Machi, Omachi, Tsutsumi Machi, Kokudo Tatemono Sokatsu, and the main roads in the public house area. The Tokoku 93 Unit also assisted by clearing away fallen communication lines.

g. Restoring communication lines. Immediately after the attack, all communication lines were out, but, with the aid of communication officials and communication bureau personnel, the communication bureau and police telephone lines were restored five minutes after the fires were put out.

h. Disposal of dead bodies. With the aid of the special guard unit and one section of the civilian-defense unit, a mortuary unit was formed which disposed of bodies in the following manner:

When the bodies were discovered, sheets of metal were put over them and they were then placed at the side of the roads. Tags were attached which listed sex and place where body was found. They were then taken and assembled at the Sannai Cemetery.

i. Ominato Coast Guard District. At about 0500 hours, 29 July, this organization dispatched two ships to aid in relief work. Five hours later two more ships were dispatched loaded with food and clothing.

j. Governmental agencies. At 1000 hours on 31 July, various governmental agencies, including the Army, met in Aomori and discussed plans concerning their future action.

k. Transportation

(1) *Railroad transportation.* As a result of the attack, 13 box cars, 17 passenger cars, and some trackage were damaged. Although this had a temporary adverse effect, rail transportation was soon restored to normal.

(2) *Automobile transportation.* Trucks and busses were dispersed as soon as the attack began. Seven trucks, 7 busses, and approximately 15 percent of all other vehicles were either completely burned or rendered unserviceable. In accordance with previously made plans, serviceable automobiles were pooled and used by the Aomori Transportation Headquarters for the following purposes:

(a) Transportation of dead bodies.

(b) Transportation of emergency rations, clothing, and other necessary items.

(c) Transportation of relief workers.

(d) Transportation of communication repair equipment.

(e) Transportation of intelligence reports.

(3) *Sea transportation.* Because of the lack of electrical power, ships could not be unloaded until 31 July. Coal, however, was immediately unloaded by using 10 percent of the workers of the Nippon Tsun Branch Office, 357 Korean laborers and 420 soldiers.

1. *Electric power.* The restoration of electric lighting was given first consideration because of its effect on morale. Power was restored by 1900 hours on 29 July in the principal offices, such as the Aomori Railroad Station, Aomori Radio Station, and Tohoku 93 Unit Headquarters, through the efforts of the Aomori branch of the Tohoku Power Distributing Corporation. By 31 July, practically all the important buildings in Aomori and its suburbs had electricity.

m. Morale. In order to raise the morale of the people, propaganda posters were printed and distributed urging the people to keep their spirits up.

n. Building inspection. An inspection was made of all buildings still standing to determine whether or not they could be used.

o. Public toilets. In order to maintain proper hygiene standards, 100 public toilets were established.

p. Outside aid. Immediately after the attack, the radio volunteer units of Hirosaki and Hachinoche did the following:

(1) Posted propaganda posters in 50 localities. These dealt with the bolstering of morale of the average citizen.

(2) The Volunteer Mobile Radio unit transmitted the methods of receiving and distributing food, of getting aid to Aomori, and of evacuating the victims from the various assembly points. It also transmitted information concerning the location of relief stations. In addition, it attempted to counteract false rumors.

(3) It transmitted the orders of the prefectural governors as well as those of the Aomori police chief to the two Nippon Daily newspapers and to all police stations.

(4) On 30 July, assistance was obtained from the Sambongi Machi Volunteer Radio unit which organized a mobile radio receiving unit and also a public address system for disseminating propaganda.

(5) This unit constructed and distributed bulletin boards throughout the city for the posting of official notices. Seven suggestion boxes were also distributed, in order to encour-

age the people to give their ideas of the manner in which relief should be effected.

q. Koreans. It was reported that 271 Koreans were assembled and evacuated. One was listed as missing. However, for the present, this is not an important matter.

r. Food Distribution

(1) *Immediately following the attack.* The victims were supplied with rice balls from the neighboring suburbs. Each person was supplied free with 1 "Go" which was supposed to last 3 days.

(2) *Food distribution centers.* Ten food distribution stations were established in Aomori. After 1 August, rice, miso sauce, shoyu sauce, vegetables, meat, and milk distribution was effected with a minimum of effort, and there were no serious problems to be considered.

(3) *Manufactured straw goods.* According to previous arrangement, there were supposed to be 9,000 straw mats, 24,000 pounds of rope for shelters and temporary huts and 15,000 straw bags to be used for unloading coal. By 31 July, 25,000 straw mats, and 2,000 straw bags had been obtained.

Battle Lessons

(Translator's Note. This is a list of the lessons that the Japanese have learned as the result of the attack. It will be noticed that in practically all cases recommendations are made for future action.)

1. *Evacuation of personnel.* The evacuation of personnel following this attack was successfully carried out. However, in view of the possibility of further attacks, the evacuation of young, old, sick, and pregnant should be encouraged. As the result of the carrier attacks of 14-15 July, the evacuation in this attack was improved, and, even though this was a particularly heavy attack, the casualties were comparatively light, in spite of the fact that 90 percent of the city was completely burned. In view of the fact that many old people who had not been evacuated were casualties, the evacuation of this class of personnel should be emphasized.

2. *Evacuation from buildings.* Because of the existence of streets which were widened to 50 meters to serve as firebreaks, the evacuation from buildings in Aomori was carried out rather successfully, in as much as these wide streets acted as excellent avenues of escape.

(Translator's Note. The writer of this document goes on to say that, if the spread of fire is to be prevented, the streets should be widened to a minimum of 100 meters and wherever possible should run along streams.)

3. *Home fire fighting.* There were many casualties because people made the mistake of fighting the fire and thereby lost the valuable time needed to flee from the area.

4. *"Godowns."* Immediately after the outbreak of the fire, the doors of the vaults (Godowns) which were hot were opened and consequently the fire ignited the contents of these buildings. Water should always be placed inside these storehouses and after the fire around them has been extinguished the doors and windows should be opened. However, this was done in Kome, Machi, Kitaga, and Kohachi, and fires broke out.

(Translator's Note. Apparently in these cases the contents of the vaults were smoldering due to fires being started therein by radiation. Upon the admission of oxygen, ignition resulted.)

5. *Motor vehicles.* One of the important lessons learned from this attack was that trucks, busses, fire apparatus, and other motor vehicles should be dispersed outside of the city or at least outside of the area that is burning, and should be so located that they will not be subjected to exposure fires. During this attack, in accordance with the plan of action, the fire trucks were dispersed within the city and their effect was practically nil because of the intensity of the attack.

6. *Shelters:*

(Translator's Note. In this phase of their report, the Japanese very obviously contradict themselves, particularly in so far as the use of shelters is concerned. It is felt, however, that the inclusion of this part of their report will prove interesting, and it is transcribed herewith as literally as practicable.)

a. Underground shelters. It is recommended that 6 inches of earth be placed over materials stored in shelters located under houses. In all cases where this had been done, the materials, particularly food, were found to be safe. (This recommendation is particularly applicable in as much as this type of shelter was common throughout the city.)

b. Recommended type of shelter. It is recommended that air-raid shelters be constructed with their roofs at least three feet above the ground, covered with earth and provided with two entrances, each of which should have a curtain made of incombustible material. In addition, a barricade should be constructed so that if there be a fire near by or a near miss the shelter will be protected. This type of shelter was used at the Yokouchi Chemical Factory in Osaka Machi in Aomori. This plant received hits and fires broke out, but the shelters which were within six feet of the burning buildings were not affected. In one case, two incendiary bombs hit near the entrance of a shelter of this type in which there were four persons, and, although a fire burned right outside, the occupants were not harmed.

c. Use of shelters. It is dangerous to escape to a shelter at the time of an air attack. During this attack, those who escaped to incompleted shelters lost valuable time and in the end burned to death. The majority of deaths in this attack was among those who escaped to shelters. Also, since shelters were constructed near dwellings, there were cases where people died because the fire spread into the shelter. In Tobago Machi there was a number of shelters that had been flooded, and the water in them was used advantageously by the people to douse themselves, thus preventing their clothing from catching fire.

7. *Evacuation by water.* Those persons who were able to escape to the shore of the bay were saved because the Aomori Water Police Department had its floats and small boats ready to receive them. Also, the fact that there was no off-shore wind blowing at the time added to the safety of escape by water.

8. *General comments*

a. Since the police department had informed the people at the time of the attack regarding the roads to be taken in evacuating the city, the losses were comparatively light.

b. During an attack, some sort of head protection is necessary. When evacuating, carry buckets full of water. If the eyes and throat hurt because of the hot wind and smoke, soak a towel and apply it to the mouth, eyes, and nose. In this manner, the evacuation will be completed easily; moreover from time to time cover the clothes to prevent their catching fire.

Appendix B

Kawamura Match Factory Fire Report, Aomori, Japan

On the night of 6 November 1945, fire which started in an over-heated, fire-resistive, dry-room destroyed the property of the Kawamura Match Factory (Figure 5). The fire burned for a period of 50 minutes and completely destroyed the combustible portions of the structure.

The Kawamura Match Factory manufactured wooden match sticks. The manufacturing process involved a simple procedure of cutting match sticks to proper size, packaging and wrapping the sticks in rice-straw for shipment elsewhere for impregnation. There was no impregnation process involved at this location.

Heavy de-barked logs, cut to 12-inch lengths, were soaked in hot water in a wood-shavings-fired metal-clad wood vat. The log "chunks" were then "skinned-off" in an electric-power rotary shaver, cut to desired size in an electric power shear, dried in a brick-enclosed hot-air dry room and dressed off in an electric-driven tumbler. After a hand-sorting process, the sticks were packaged and tied and then bundled in rice-straw wrappings and shipped for impregnation.

The factory was a typical one- and two-story wood-frame structure with no basement. Outside walls were frame and frame metal-clad. Floors of sections occupied as dwelling quarters were raised wood boarding carried on light

Japanese recapitulation of damage and losses

AOMORI

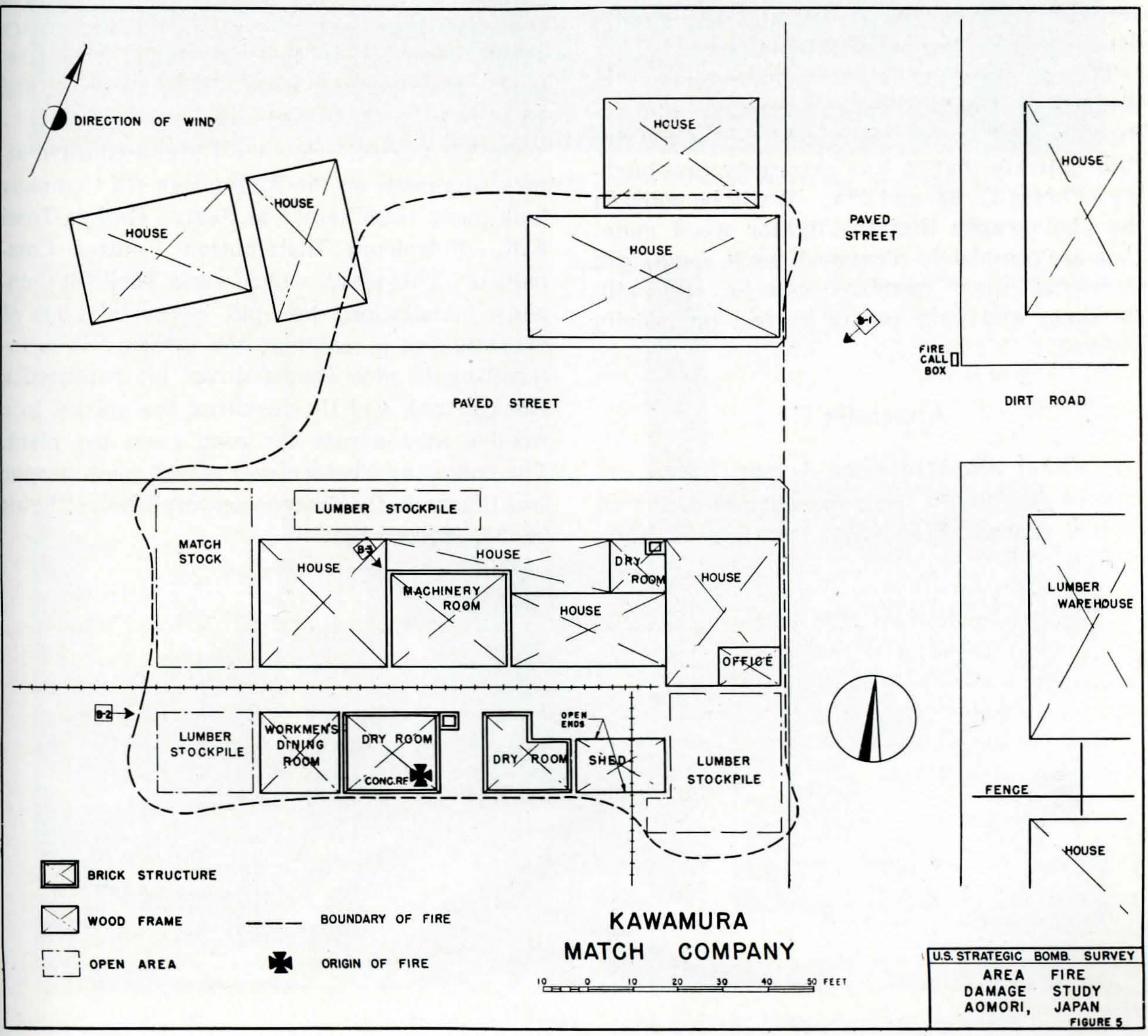
Bombs dropped	Personnel losses				Building losses		Ships		Structures		Railroad		Fire department
	Dead	Seriously wounded	Slightly wounded	Whereabouts unknown	Families	Number of houses	All burned	Half burned	Buildings	Warehouses	Freight cars	Passenger cars	Vehicles
50,000	728	40	240	8	17,843	11,330	25	2	10	15	43	18	19

wood joists. There were no wood floors in the manufacturing sections, only trodden earth. Ceilings were finished only in dwelling quarters where they were of light suspended boarding. A light roof framing of wood trusses carried a sheet-metal-clad planked roof. A small brick-enclosed dry-room was roofed with 4-inch concrete slab over which was built a light-wood frame attachment. This fire-resistive enclosure communicated with the combustible manufacturing areas through unprotected openings.

Thirty-five percent of the factory area was of light-wood frame construction and was occupied as dwelling quarters. This construction was contiguous with the mixed-constructed manufacturing area of about 32 percent, the superior constructed fire-resistive area being 6 percent. The remaining 33 percent of the area was used for open storage of raw materials and finished products.

On the night of 6 November 1945 at 2100 hours, a fire broke out in the frame attachment over the fire-resistive dry room. An unattended brick-set low-pressure steam boiler in the dry room ignited loose rice straw in this same area. This incipient fire spread to similar contents in the frame attachment over the roof through unused and unprotected pipe holes in the concrete roof.

The factory site was a half-mile from the nearest fire station. Fire department apparatus arrived in response to an alarm within ten



minutes after the fire was noticed. During this period of time fire-fighting efforts were of a first-aid nature with only passers-by participating. Upon arrival of the fire department, the fire had spread to the extent that the entire factory site was involved. The main effort of the fire department was, therefore, directed toward limiting the extent of this spread.

Within 50 minutes of the time the fire was noticed, and within 40 minutes after the fire department arrived, the fire was extinguished. In this short span of time, 6,000 square feet of ground floor area of the factory had burned out, the fire had spread across 45 feet of clear space and had burned out 1,450 square feet ground floor area of a dwelling which was exposed across a 30-foot-wide street, and had lightly damaged two other exposed buildings.

This factory was highly vulnerable to fire because of combustible construction and occupancy, and certain characteristics of the fire ruin indicate that it was extremely fast-burning (Photos 27, 28, and 29). It will be noted in the photographs that the lighter wood materials are completely consumed, while some light structural wood members can be seen still standing, and only partly burned or heavily charred.

Appendix C

Other Air Attacks on Aomori Area

In addition to the incendiary attack described in this report, there was a number of high-explosive attacks made on the Aomori area.

On 14–15 July 1945, there was a number of repeat attacks made on both the city and the shipping in the harbor. In addition to dropping high-explosive bombs, the planes also strafed the streets. On the fourteenth, as a result of an attack on shipping in the harbor, a ferry boat was sunk with the loss of 102 persons. In addition, 10 persons were seriously injured and 5 were slightly injured. On the fifteenth, 2 were killed and 3 injured as the result of strafing.

On 10 August, according to the Japanese, four carrier-based planes delivered a low-level attack on the city, and dropped a number of high-explosive bombs which did little physical damage, because the bombs dropped on the area that had been burned out by the incendiary attack described in the main body of this report. Five persons were killed, however, and 15 were injured, 10 seriously.

On 10 August, a low-level high-explosive attack was made on the Rising Sun Oil Company bulk plant (also known as Sekiyu Haikyu Tosei K.K.—Petroleum Distribution Control Company). This plant, which was a Shell Oil Company installation, was put completely out of operation as a result of the attack. It is interesting to note that a direct hit ruptured a storage tank and the resulting fire spread to a wooden area across the road from the plant. The following "before and after" photographs best illustrate the damage accomplished (Photos 30, 31, 32, and 33).

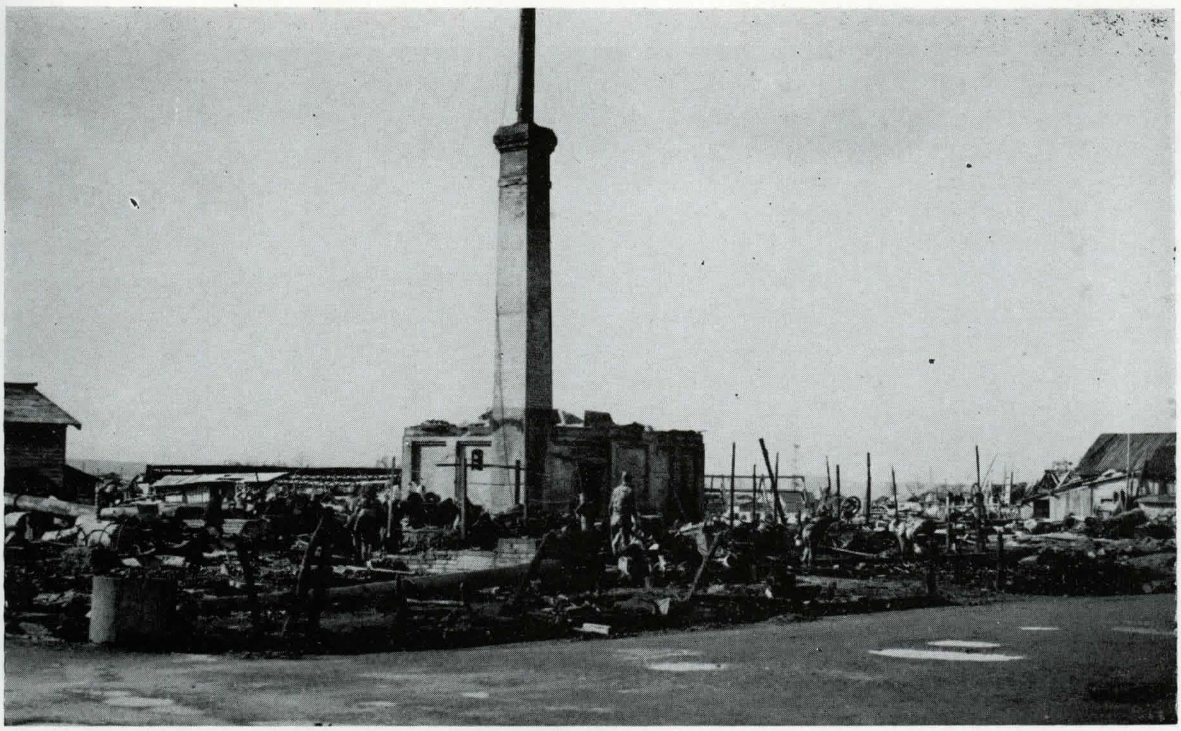


Photo 27.—Kawamura match factory fire damage. Brick enclosure houses dry room and boiler.

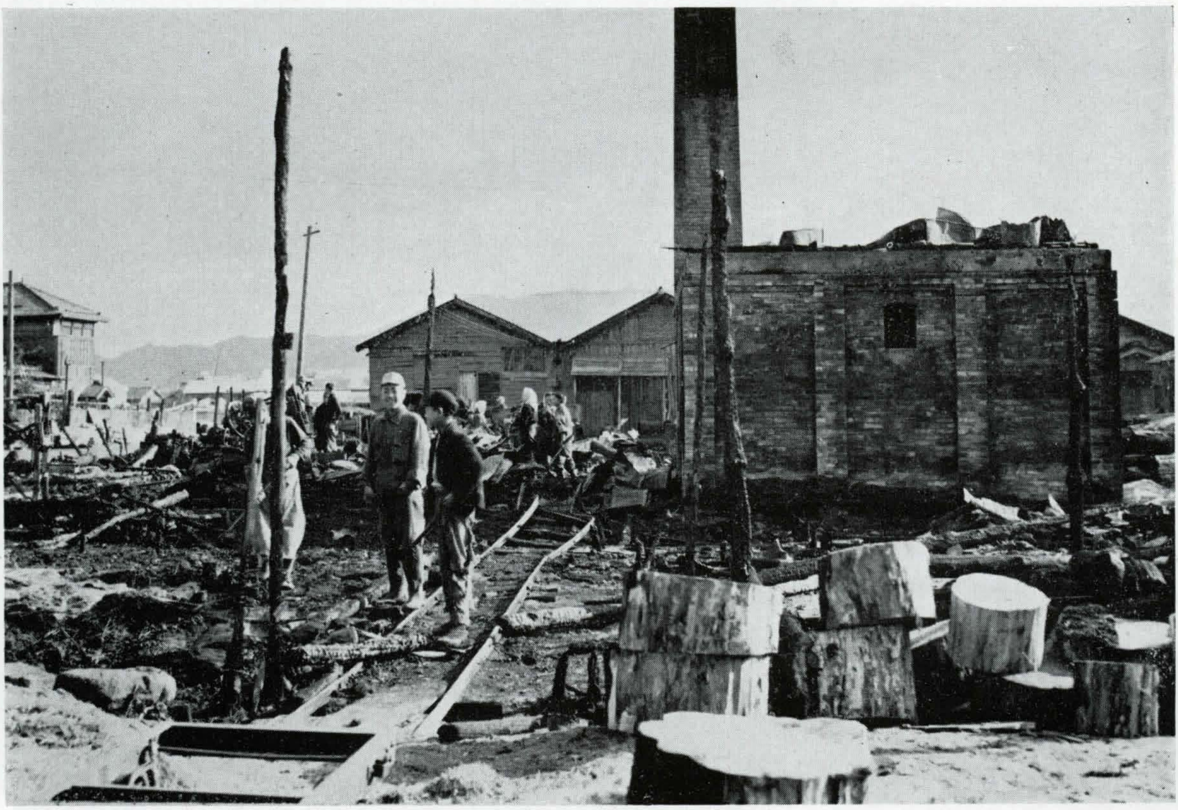


Photo 28.—Kawamura match factory fire damage. Brick enclosure houses dry room and boiler.

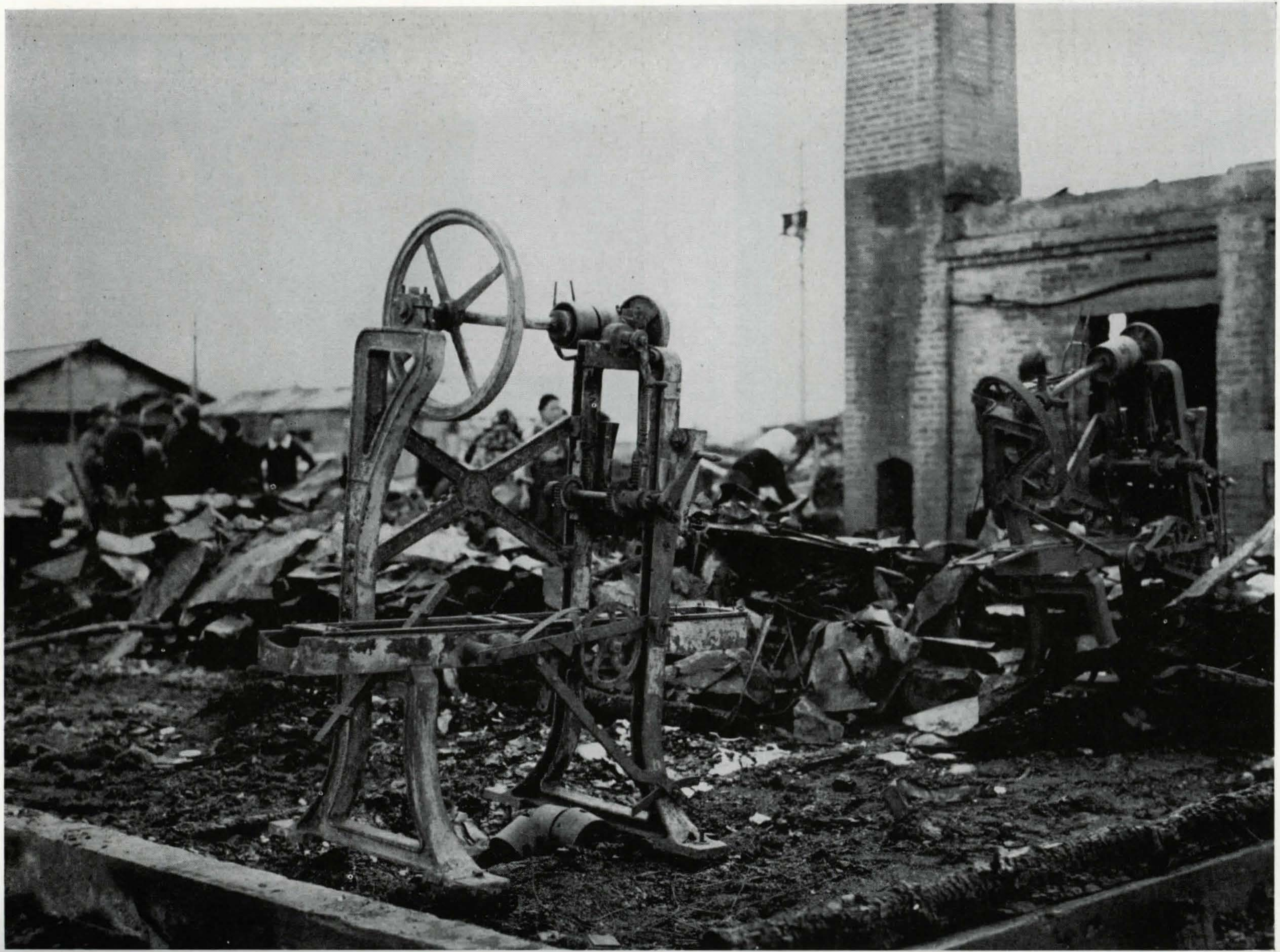


Photo 29.—Fire damage to machinery and equipment. Note sheet steel from roof and walls.

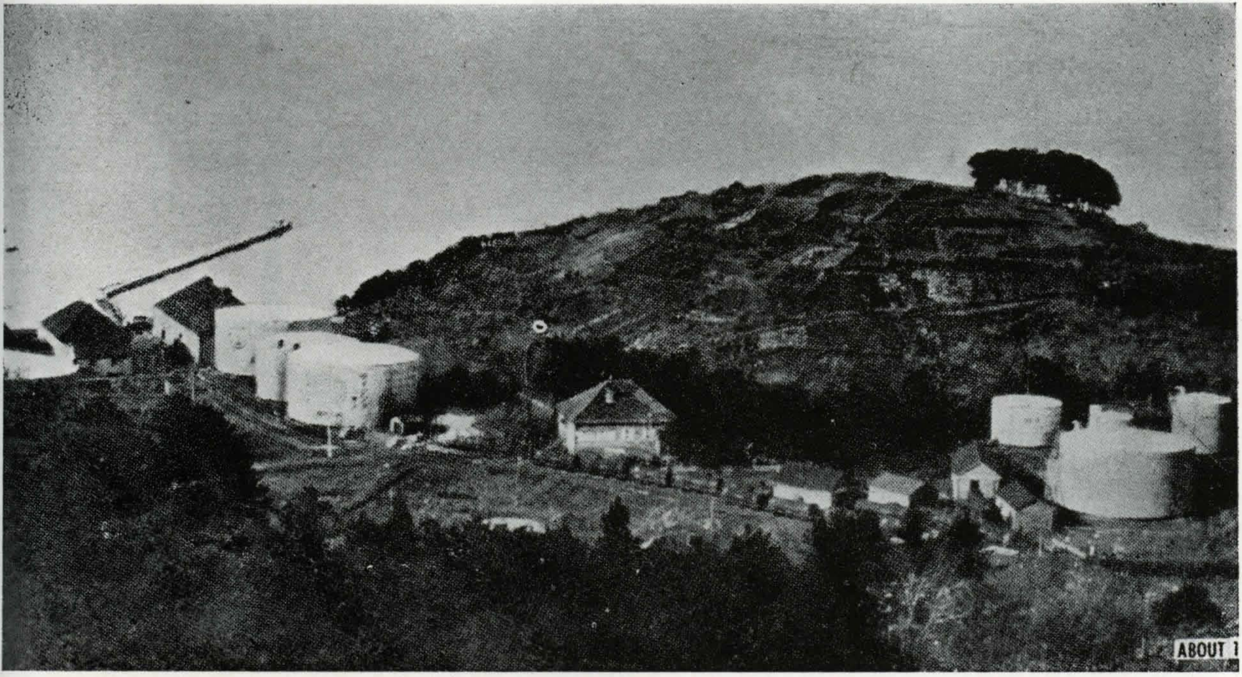


Photo 30. — Noni storage plant, Rising Sun Oil Co. Pre-raid view.

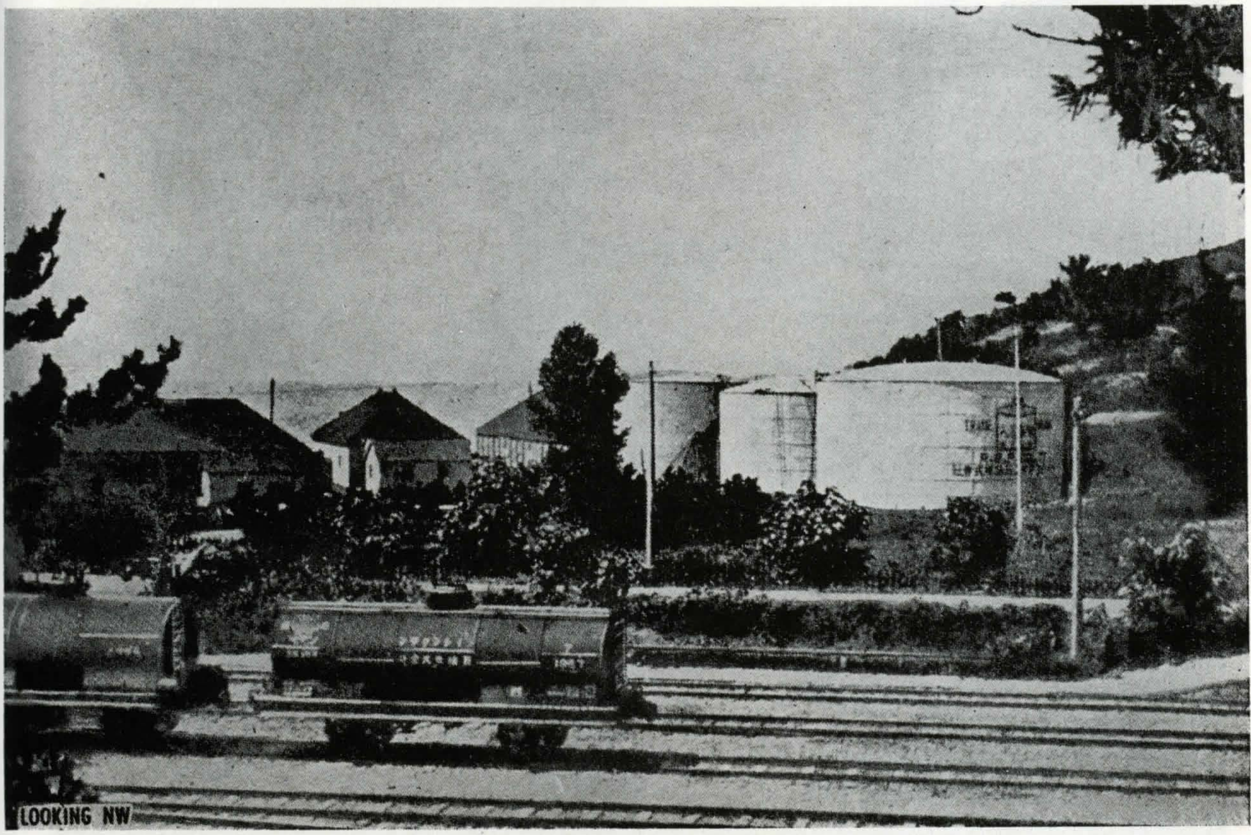


Photo 31.—Noni Oil Storage Plant.

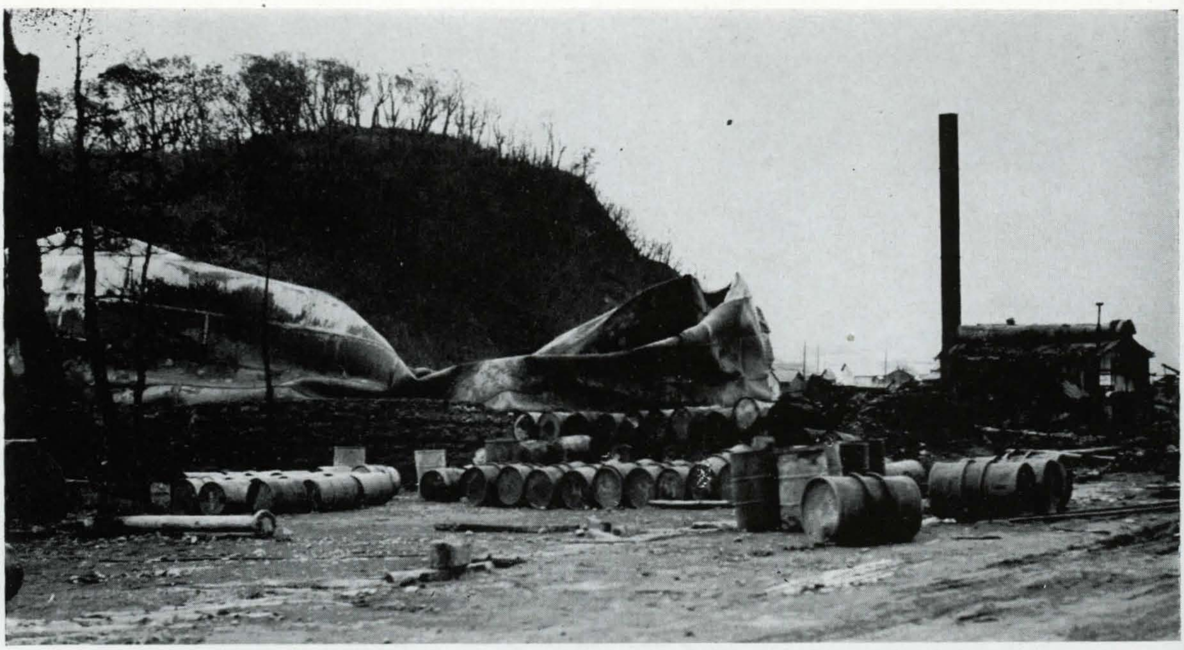


Photo 32.—Result of direct hit on fuel oil storage tank of Rising Sun Oil Co., bulk station, Noni.

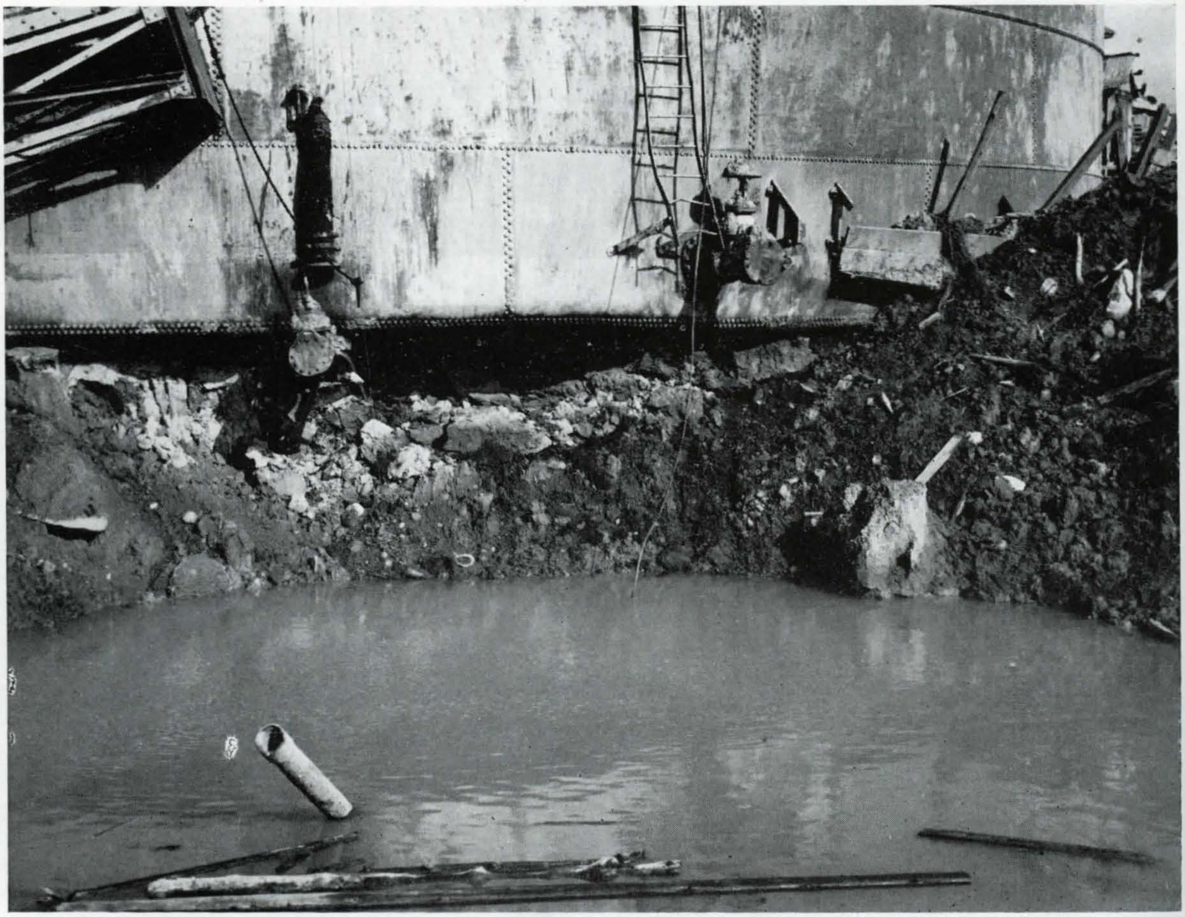


Photo 33.—Damage to tank resulting from HE near miss. Rising Sun Oil Co., Noni.

Part 5

EFFECTS OF INCENDIARY BOMB ATTACK ON AKASHI, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 161

II. SUMMARY 161

III. GENERAL INFORMATION 161

IV. THE TARGET 161

V. ATTACK DATA 163

VI. DEFENSE AGAINST AIR ATTACK 164

VII. THE FIRE 164

VIII. DAMAGE 165

IX. ANALYSIS OF DAMAGE 172

X. RECUPERABILITY 177

XI. CONCLUSIONS AND COMMENTS 177

APPENDICES A AND B

Photos 1-25, inclusive

Figures 1 and 2

Fire Damage Study, Akashi, Japan

I. Object of Study

1. The object of study was to determine the effectiveness of the M69 bomb and the extent of fire damage in a single air attack against a Japanese city.

II. Summary

1. Akashi is a small industrial city situated on the Inland Sea about 14 miles west of Kobe. Its population was about 50,000 normally, but had almost doubled following the China Incident, due principally to the establishment of the Kawasaki Aircraft Plant and the expansion of existing industrial plants converted to war work, mainly as subcontractors to the Kawasaki plant.

2. More than 90 percent of the city was 20 percent or more built up. The southern part of Akashi was the most heavily built up and was comprised chiefly of one- and two-story frame dwellings and dwelling-shop combinations with an intermixture of modern, well-constructed office buildings. The main industrial section was located along the western edge of the city. The city of Akashi provided a target of approximately 768 acres of built-up area.

3. The dispatched load of this mission was reported as 1045.2 tons of the M69 incendiary bomb and the reported delivered bomb load on the target was 975 tons.

4. An estimated 47 percent of the total built-up area of the city was destroyed or damaged as a result of this attack. Of the total built-up area subjected to attack, which included the city of Akashi and its suburbs (1,130 acres), it is estimated that 680 acres, or 60 percent, was destroyed or damaged by the attack.

5. As a result of this attack, 576 casualties were sustained, including 355 dead, 57 injured, 133 slightly injured, and 31 missing. A total of 9,075 dwelling structures was destroyed or damaged as were seven government buildings, three schools, 10 larger factories, and four warehouses.

III. General Information

Team personnel and time of survey. The following personnel constituted Team 12 which conducted the fire damage study of Akashi during the period 16 November to 25 November 1945:

Capt. Robert H. Merz	Team chief and fire engineer.
Capt. Elmer R. Hjortsberg	Fire engineer.
Lieut. (jg) Maurice Hellner	Interpreter.
Sgt. John Cherry	Clerk-driver.
S 1/c Robert McClintock	Draftsman.
PhoM 3/c William Mattern	Photographer.

IV. The Target

1. *Geographical.* Akashi is an irregularly shaped city lying along the coast of the Inland Sea approximately 14 miles west of Kobe. It lies within Hyogo Prefecture and is on the main line of the Sanyo Railroad which runs between Kobe and Shimonoseki (Figure 1). The metropolitan section of the city occupies a built-up area of 1.2 square miles. In 1940, the west boundary of Akashi was relocated, as shown on the map, in order to include the property of the Kawasaki Aircraft Plant. The area within the new boundaries is known as Greater Akashi. The city is divided into a north section and a south section by a 50-foot-wide highway running through it. On the west, the Akashi River separates the main section of the city from the industrial section and Greater Akashi.

2. *Population.* In 1940, the population of Akashi was 48,000. This figure, however, rose to 84,000 because of the inclusion of more area within the city and the establishment of the Kawasaki Aircraft Plant, many employees of which were recruited from areas outside of Akashi.

3. *Street plan.* With the exception of the main street which runs through the center of the city, and a few other arterial streets, the streets are narrow, and in many cases, extremely irregular.

4. *Built-upness.* The south section of the city, the most congested area, was comprised mainly of one- and two-story frame dwellings with an intermixture of modern, well-constructed public and business buildings (Photo 1). The principal industrial section was in the western part of the city in the vicinity of the

Akashi River. The following table shows the relative built-upness of Akashi:

Acres	Square miles	Percent of total area	Percent of built-upness
153	0.24	20.0	40 or more (dense).
542	0.85	70.5	20–40 (medium).
73	0.11	9.5	5–20 (sparse).
768	1.20	100.0	

5. *Industries*

a. Peacetime. Peacetime industries of Akashi included the manufacture of match sticks, small ship engines, farm tools and implements; building of fishing boats; and weaving of cotton textiles. A small fishing fleet was active, but most of the catch was consumed locally. In addition to these activities, there was a considerable tourist trade, Akashi being one of the popular seaside resorts on the Inland Sea.

b. Wartime. The largest single wartime industry was the Kawasaki Aircraft Plant located west of the Akashi River in Greater Akashi. This plant employed 40,000 persons and was one of the most important of its kind in Japan. Other plants engaged in war work in Akashi, including a steel plant and an oxygen-apparatus plant, were engaged in sub-contract work for the Kawasaki Plant.

6. *Types of construction*

a. Dwellings. The typical Akashi dwelling was a one- or two-story, wood-frame structure with a wood-truss, low-pitched roof, covered with tile laid in a mud mix over ½-inch boarding. Exterior walls were either a ½-inch wood curtain wall carried on the frame, or were built up of mud mix carried on a light wood or bamboo lattice, and finished with a plaster coating or wood sheathing. Floors were either hard-trodden earth or ½-inch boards carried on joists. Light ¼-inch ceilings were suspended from roof trusses, and, in many cases, had been cut away to allow ready access in the event of fire in an otherwise concealed space. Interior partitions were constructed of either ½-inch wood strip or bamboo lattice covered with wallboard or paper. This highly combustible type

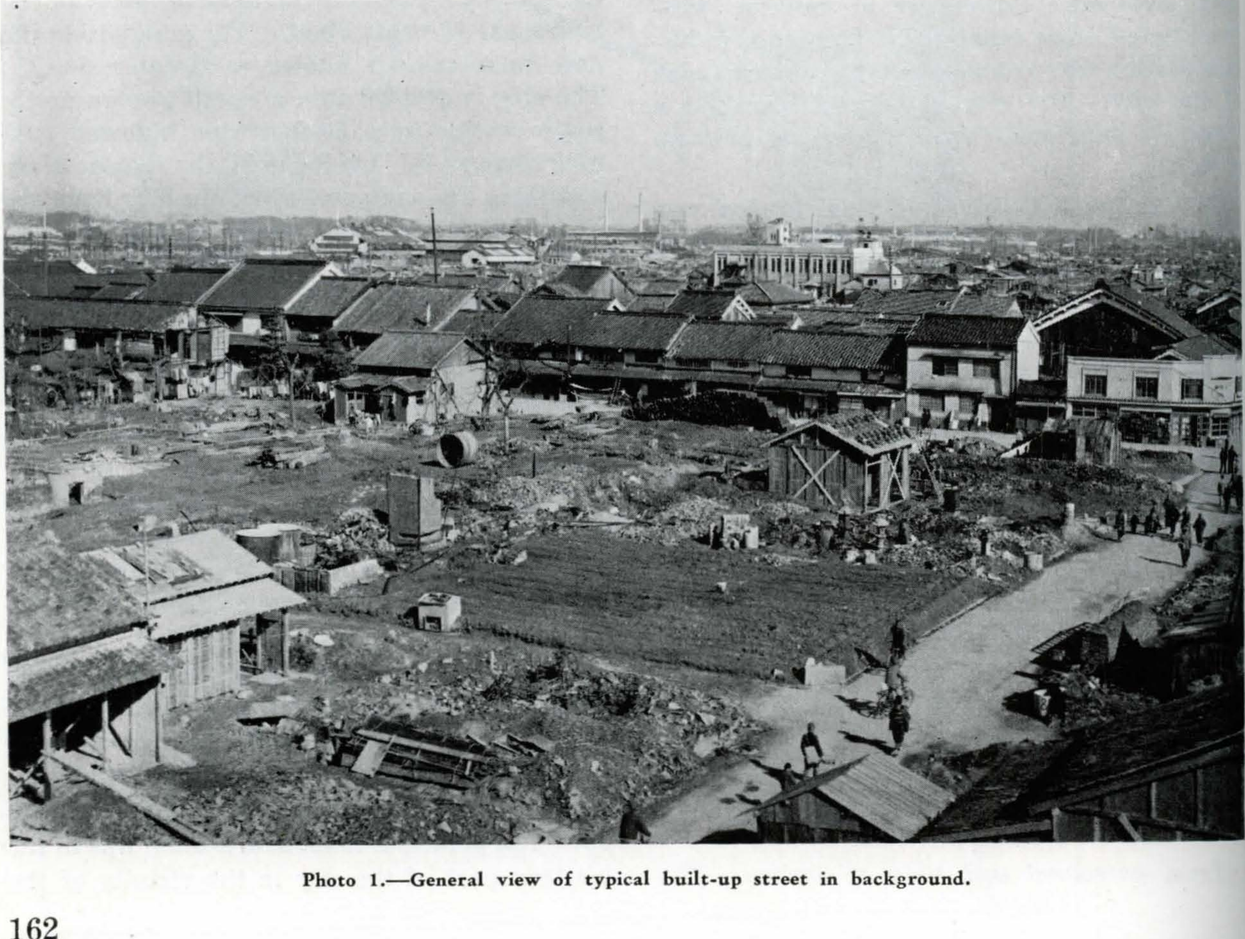


Photo 1.—General view of typical built-up street in background.

of construction, averaging 500 square feet of floor area, prevailed throughout Akashi.

b. Home workshops. Small home workshops were often found in connection with dwellings, occupying the same structure or small, wood, lean-to additions contiguous to the dwelling. The principal difference in construction was the absence of the raised wood floor. Numerous small commercial and mercantile occupancies were found in similar structures.

c. Industrial buildings. The larger industrial buildings of Akashi ranged in size from 10,000 square feet to 50,000 square feet of ground floor space, and usually had one or two stories. The structural frame was either heavy timber or a combination of timber and steel with a correspondingly constructed truss roof. Exterior walls were of wood, corrugated iron, or sometimes of corrugated asbestos cement; this same material was also used for roof covering. Floors were either concrete on fill laid on ground or hard-trodden earth. The use of brick was rare and ordinary load-bearing brick-wall structures were most uncommon. Although there was little or no attempt at special construction to house specialized industrial processes, the use of brick was sometimes noted in connection with drying occupancies and boiler houses. Although the general industry of Akashi was varied, the industrial construction was preponderantly combustible with a few noncombustible structures. There were no cases of fire-resistive industrial construction.

d. Public buildings. There was no general type of construction noted among public buildings. Some, such as the railroad station and outlying public schools, were combustible, while other structures, particularly the administrative buildings, were fire resistive. A few of the administration buildings were of modern reinforced-concrete design, generally two stories in height with reinforced-concrete slab roofs and floors.

8. *Vulnerability.* The city of Akashi was extremely vulnerable to damage by an incendiary attack for the following reasons:

a. Approximately 95 percent of the buildings in the city were combustible.

b. The combustible buildings, with few exceptions, were contiguous and were in congested areas.

c. Streets were generally narrow and irregular and provided poor avenues of approach for fire apparatus.

d. Public fire protection was poor, due mainly to the lack of dependability of the public water system.

e. Natural and man-made firebreaks were few in number.

V. Attack Data

1. *General.* The night attack on Akashi was included as Mission 252 in Field Order 96, Headquarters XI Bomber Command, Twentieth AF, dated 6 July 1945, which directed five attacks on Honshu. The force that attacked Akashi consisted of 4 groups of the 73rd Wing made up of 124 B–29s, including 12 pathfinder planes.

2. *Load data.* The planes were loaded with E46 clusters fuzed to open 2,500 feet above the target with an intervalometer setting of 50 feet. Each cluster carried 38 M69 incendiary bombs and weighed 425 pounds. The M69 incendiary bomb weighs 6 pounds and has a hexagonal case, 19.5 inches long and 2.8 inches in diameter. It is filled with 2.8 pounds of gelled gasoline and has an incendiary fill weight ratio of 46 percent. It is provided with 4 gauze tail streamers, 47 inches long, to stabilize the bomb in flight and to reduce the terminal velocity.

3. *Attack data tables*

a. Flight data

Mission number	Date of attack	Primary target	Planes	Time over target
252	6-7 July 1945.	Akashi, Honshu.	124 B–29's	0015 to 0127 (local time).

Altitude	Weather	Wind	Cloud cover
6900 to 8200 ft.	Light rain.	23 m.p.h. 8000 ft.; 5 – 10 on ground.	4/10 to 8/10.

b. Bomb data

Clusters loaded on airborne aircraft		Released on target		Cluster opening altitude	Intervalometer setting
Number	*Tons*	*Number*	*Tons*	*feet*	*Feet*
5,226	1,045.2	4,875	975.0	2,500	50

NOTE.—In addition, 11 M46 photoflash bombs were dropped to facilitate night photography.

4. *Other attacks* (Appendix B)

a. Prior to the incendiary attack of 6–7 July 1945, Akashi had received four attacks which were directed against the large Kawasaki Aircraft plant west of the city (Greater Akashi), only high-explosive bombs being used. These attacks were made on 19 January, 9 June, 22 June, and 26 June, all in 1945.

b. Consequently, a number of the areas hit by the incendiary bombs had been hit previously by high explosives, particularly in the vicinity of the river and the area occupied by the Kawasaki plant. A physical damage survey of this plant appears in a separate report.

c. In a number of cases, particularly at the aircraft plant, high explosives caused fires and it was therefore difficult to distinguish between fire damage induced by high explosives and that caused by incendiaries, except where individuals were found who could recall the details.

d. A map of Akashi on which the fire chief has shown the extent of damage caused by the two types of bomb attacks is filed in the U. S. Strategic Bombing Survey G–2 Library as: Akashi Reference No. 1, Physical Damage Division Reference Notes.

VI. Defense Against Air Attack

1. *Civilian*

a. Fire department. Prior to the attack, the personnel of the Akashi fire department consisted of 200 full-time firemen and 1,000 volunteers. The latter were not volunteers in the true sense of the word, but comprised those who were assigned fire-fighting duties by the auxiliary police and fire units as their required contribution to the war effort. At the time of the survey, however, the personnel of the regular department had dwindled to 130 full-time firemen and an indeterminate number of volunteers. Before the attack, the department had 30 pieces of motorized fire apparatus, half of which were in Akashi proper and the remainder distributed among the neighboring rural communities which were under the protection of the Akashi fire department. In addition, Akashi had a mutual assistance agreement with Kobe, in accordance with which Kobe was to send 30 pieces of apparatus to Akashi in the event of an air attack.

b. Water supply. The water supply was obtained from three wells, each approximately 400 feet deep. The water was pumped from these wells through the treatment plant and into a 200,000-gallon-capacity reservoir from which it flowed by gravity through a single 12-inch supply main to the city, a distance of approximately $1\frac{1}{2}$ miles. The principal arterial mains were 10 inches in diameter and fed 8-, 6-, and 4-inch distribution mains. The waterworks was inspected during the survey and it was found that, although the pumping station and treatment plant had not been affected by the attack, they were in very poor condition principally because of inadequate maintenance and inefficient operating methods. The most outstanding deficiency at the pumping station, however, was the lack of a stand-by source of power to operate the pumps in the event of the failure of electric power which came from Osaka through a substation located in Akashi.

c. Hydrants. The fire hydrant connections in Akashi were of the sub-surface type. The hydrant riser which was carried on the fire engine had no valve stem and a separate key had to be carried in order to open and close the valve. Consequently, the hooking-up of the hydrant was a slow process. The number of hydrants was not obtained because of the lack of adequate water department records. It was observed, however, that two hydrants along the main street in the center of the city were approximately 1,200 feet apart.

VII. The Fire

1. *General.* The incendiary attack over Akashi lasted for a period of one hour and twelve minutes. During the initial stage of the attack, various defense units and the populace in general attempted to fight individual incipient-stage fires. With the increasing magnitude of the attack, however, their effort was seriously diminished, and, for the rest of the attack, fire-fighting efforts were confined to isolated burning areas where positions could be taken without jeopardy of personal safety. The general success in fire fighting was meager, however, because the bombs started many individual fires which merged into one great fire.

2. *Weather*

a. According to the Japanese, it had rained intermittently during the week prior to the attack. On the night of 6–7 July, a light rain fell both immediately before and during the attack accompanied by a 7–10-mile-per-hour wind, generally from the north-northwest.

b. Air Force weather observation made during the attack indicated 4-$^{8}/_{10}$ low clouds, tops 7,000 feet and $^{8}/_{10}$ middle clouds in thin broken layers between 7,000 and 20,000 feet. Winds at 8,000 feet were 305° at 20 knots.

3. *Fire department.* Upon receiving the air-raid "alert," fire engines were dispatched to previously determined locations within the city. Nine of the 15 engines in Akashi were at the fire headquarters building when the attack was made and were destroyed together with the building and garage. Fifteen pieces of apparatus stationed outside of Akashi remained where they were rather than leave their districts without protection. The remaining six engines were hampered in their attempts to reach the worst fires because of their inability to maneuver along the narrow, debris-covered streets and, therefore, had to limit their work to fighting fires along the wide streets in which they could move. Apparatus arrived from Kobe too late to be of any effective assistance. The main electric substation was seriously damaged by fire early in the attack (Photos 2 and 3) and that disrupted the electric power supply, putting the water pumps out of service and limiting the water supply to that contained in the 200,000-gallon reservoir. As a result, many water pumps were without water, the water pressure dropped, and the efforts of the firemen, including the 150 from Kobe, were directed mainly to rescue work.

4. *Police and military.* The prefecture police, assisted by local military units, directed a general evacuation of people from the city during the hour preceding the attack and immediately following receipt of the Osaka District air-raid "alert." The fire-fighting efforts of these forces during the attack were negligible. Following the attack, these agencies directed a general clean-up of the area, disposal of the dead, and relief measures.

5. *Communications.* As a direct result of loss of electric power and of general damage to communication lines, communications were seriously disrupted. Repairs to the network, following the attack, were limited to the more important using agencies.

6. *Evacuation.* An orderly evacuation was started one hour prior to the actual attack at the time the Osaka "alert" was received. People, carrying limited personal effects, were moved either to the open park area to the north of the city, or to the waterfront areas along the south of the city. It was estimated that about one-third of the population, primarily older adults and children, moved to the park area. Many persons, however, remained close to home and fought fires to the best of their ability.

7. *Civilian morale*

a. In general, the morale of the civilian population of Akashi during and after the incendiary attack of 7 July was fairly high and there was no panic among the townspeople.

b. Although no leaflets were dropped to warn the inhabitants of an impending raid, the people were not altogether surprised as the city had already been bombed four times, the latest being exactly two weeks before. Consequently, they were apparently prepared to fend for themselves. As the fires spread and developed, and the streets became so littered with debris that the fire engines were unable to get through, people came out of their shelters and courageously fought the fires with the only means available—buckets of water, poles, and beaters. What they lacked in fire-fighting training and equipment, they made up in some small measure by their determination, so that a number of houses which might otherwise have burned were saved.

VIII. Damage (Photos 4 and 5)

1. *Area damage table*

Built-upness	Area subject to damage		Area damaged		Percentage damaged
	Acres	*Square miles*	*Acres*	*Square miles*	
City of Akashi	768	1.20	361	0.56	47.0
Dense, 40% plus	153	0.24	137	0.21	89.5
Medium, 20% to 40%	542	0.85	164	0.26	30.3
Sparse, 5% to 20%	73	0.11	60	0.09	82.2
Suburban Akashi	365	0.57	319	0.49	87.4
Dense, 40% plus	130	0.20	124	0.19	95.4
Medium, 20% to 40%	100	0.16	71	0.11	71.0
Sparse, 5% to 20%	135	0.21	124	0.19	91.8
Total Akashi	1,133	1.77	680	1.05	60.0
Dense, 40% plus	283	0.44	261	0.40	92.2
Medium, 20% to 40%	642	1.01	235	0.37	36.6
Sparse, 5% to 20%	208	0.32	184	0.28	88.5

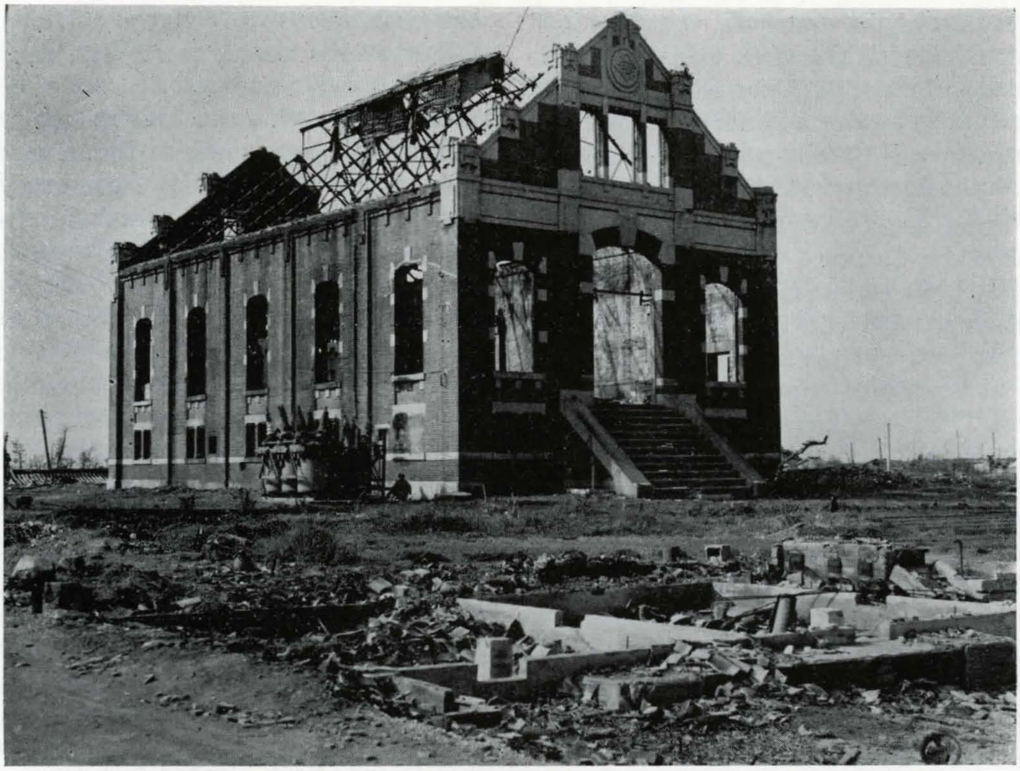


Photo 2.—Damage sustained by load-bearing brick-wall electric substation.

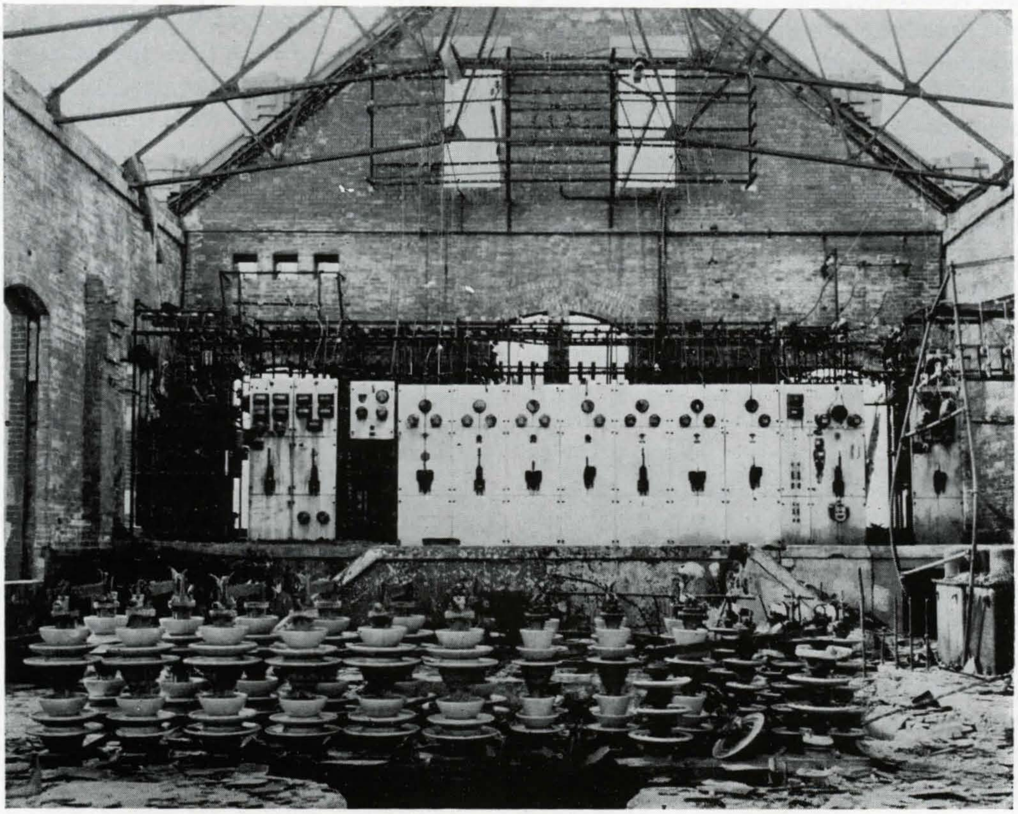


Photo 3.—Interior view of electric power substation.

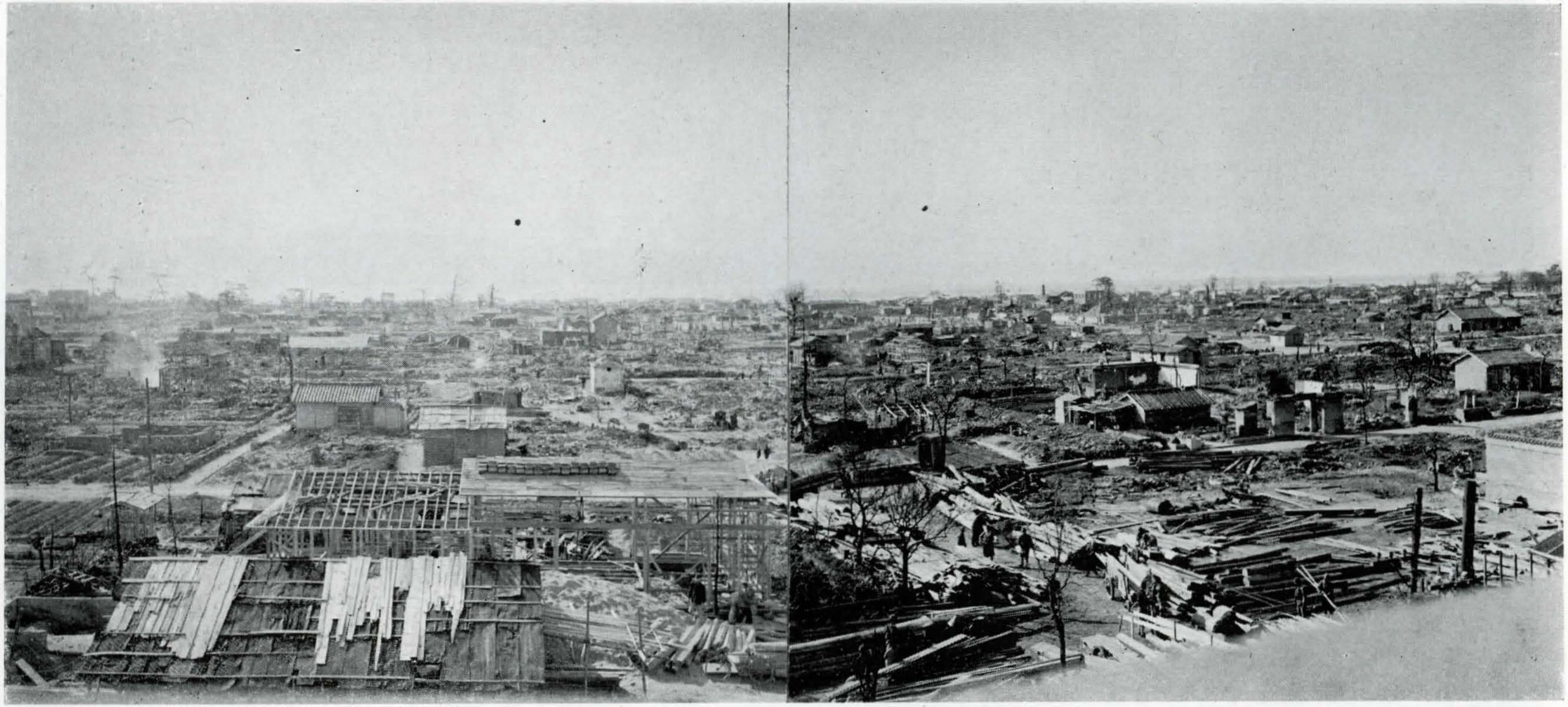


Photo 4.—General view of fire damage, looking south from center of city.

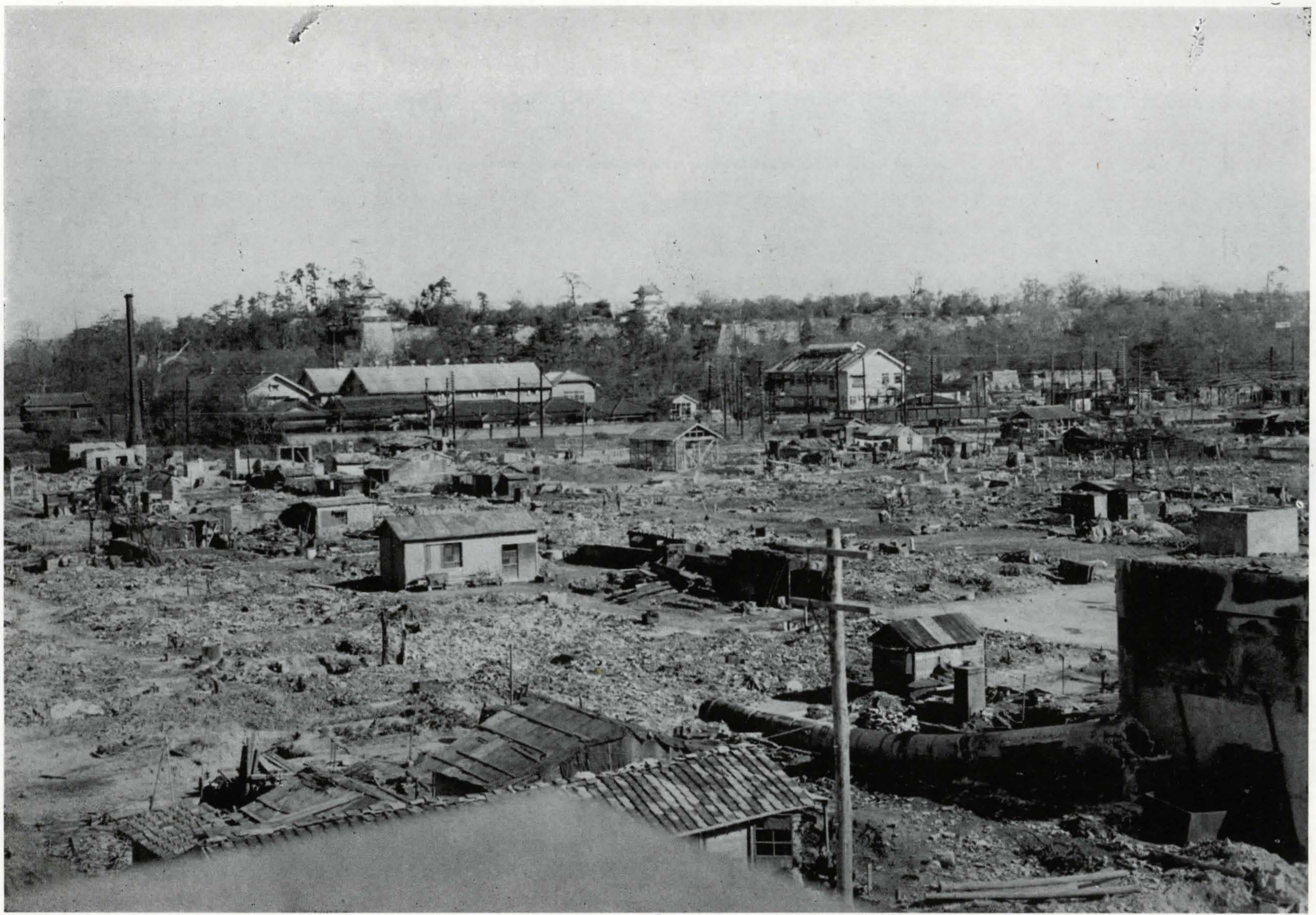


Photo 5.—General view of damaged city, looking northeast. (Stack in foreground felled in previous attack.)

2. *Casualties.* The following tabulation is based on the Japanese record of casualties resulting from the attack:

Dead	355
Seriously injured	57
Slightly injured	133
Missing	31
Total	576

3. *Buildings and industry.* The following table is based on Japanese records regarding losses due to the attack:

Damage to buildings

	Totally damaged
Dwellings	9,075
Government buildings	7
Schools	3
Factories	10
Warehouses	4
	Damaged
Electric power stations	1
Gas works	1

4. *Special study of an isolated burned area.* Fire damage in Akashi was characterized by well defined isolated burned areas, in both densely and sparsely built-up sections, as shown in the damage map of the city (Figure 1). One of these damaged sections located on the eastern edge of the city along the water front was studied in detail. An enlarged drawing of this area shows various positions where photos were taken of this fire-area perimeter (Figure 2).

a. The burned area and immediate vicinity were estimated as 40 percent built up. Remaining structures were noted to be primarily combustible dwellings, one and two stories in height, with two-story structures predominating. Interspersed were several small combustible mercantile and commercial-type structures. There were no factory structures in this area. Principal streets were from 24 to 30 feet wide and a great number of lesser streets averaged 15 feet in width. Building fronts bordered closely on street lines, and, except for varying heights in building roof lines, the buildings were contiguous on both sides of streets. Back yards had numerous sheds forming a nearly continuous built-up pattern within the blocks. Fire hydrants and numerous water tanks were in this area. No estimate of bomb density could be made by a physical inspection, the evidence in the form of bomb casings long since having been removed by the local military units. It was established by interviews believed reliable, that no incendiary bombs fell in the immediate undamaged surrounding area, and an inspection showed that there was neither damage nor newly repaired structures in it.

b. Fire started as a result of incendiary bombs within the burned area. In the general confusion accompanying the attack and in spite of a light rainfall, the fire developed gradually with the aid of a light north-northwest wind. Residents in the immediate vicinity stated that the fire burned itself out on the leeward (shore line) side to the south. Many persons, however, who had collected along the water front seeking refuge from the attack helped to control the fire, particularly along the east and west limits of the damaged area. The results of this fire fighting were apparent in many instances.

c. The following photographs show locations where fire stopped either as a result of fire fighting or as a result of a street serving as a fire break. Other factors may have had some influence upon the success of the fire fighters: first, the bomb density was not high, a light wind was blowing, a light rain was falling and many people were available to make a concentrated effort; second, the burning area was well separated from other fires, and did not burn with sufficient intensity to prevent approach by fire fighters, so that no particular personal hazard was involved.

d. Photo 6, taken within the burned area, shows the north edge of the fire limit. The buildings standing in the mid-ground were either being constructed or were undamaged. The limit of the fire can easily be seen by noting the rubble on the ground. In this position in the damaged area the wind was blowing toward the camera. The buildings shown are typical Japanese, frame-constructed mercantiles and dwellings facing a street. It is believed that the open street and the wind blowing toward the fire prevented spread at this point.

e. Photo 7 shows the limit of fire spread as it occurred at a street corner of a built-up residential block. The structure on the extreme right edge is new. The dwelling in the left center shows that part of the second-story, exterior siding has been removed. This was wood sheathed in the same manner as the front wall. It was torn off in order to stop the fire at this

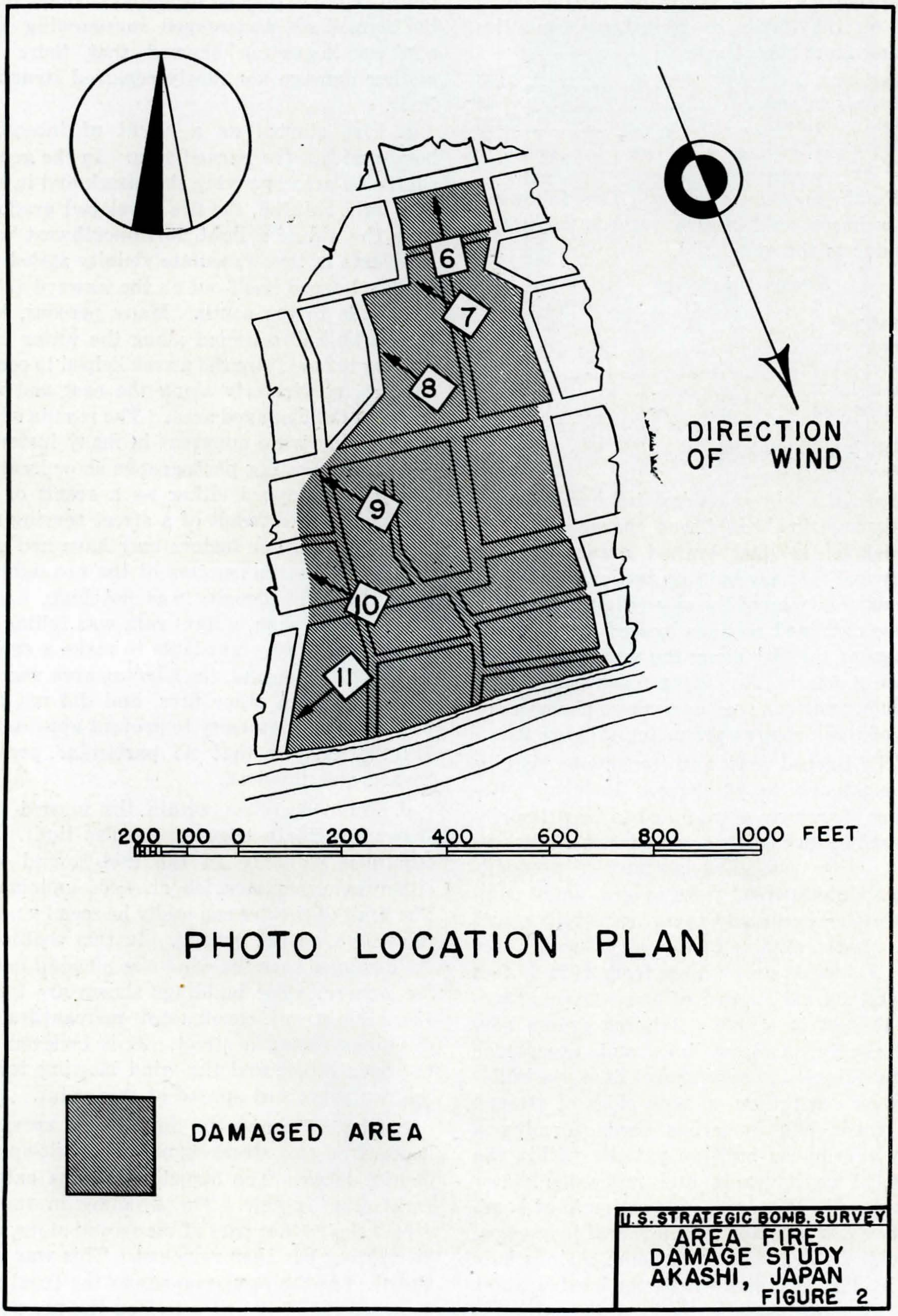


PHOTO LOCATION PLAN

U.S. STRATEGIC BOMB. SURVEY
AREA FIRE
DAMAGE STUDY
AKASHI, JAPAN
FIGURE 2

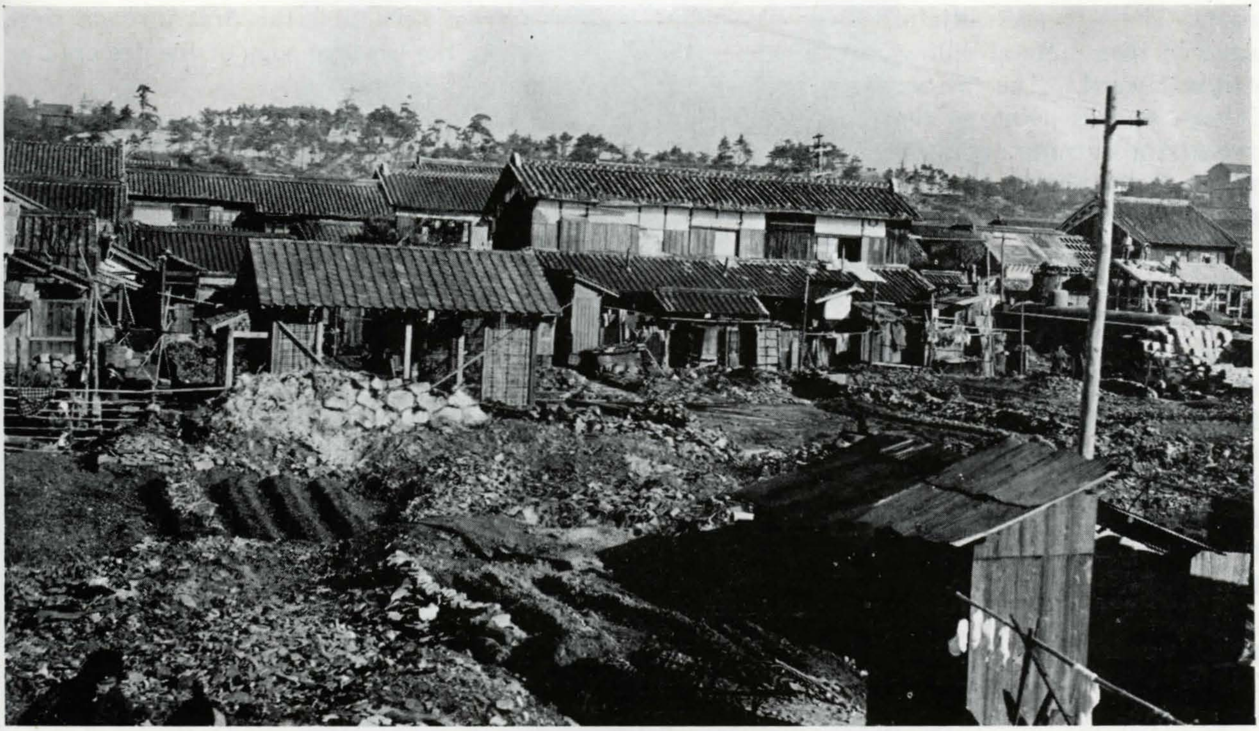


Photo 6.—Section of fire perimeter looking north and upwind.

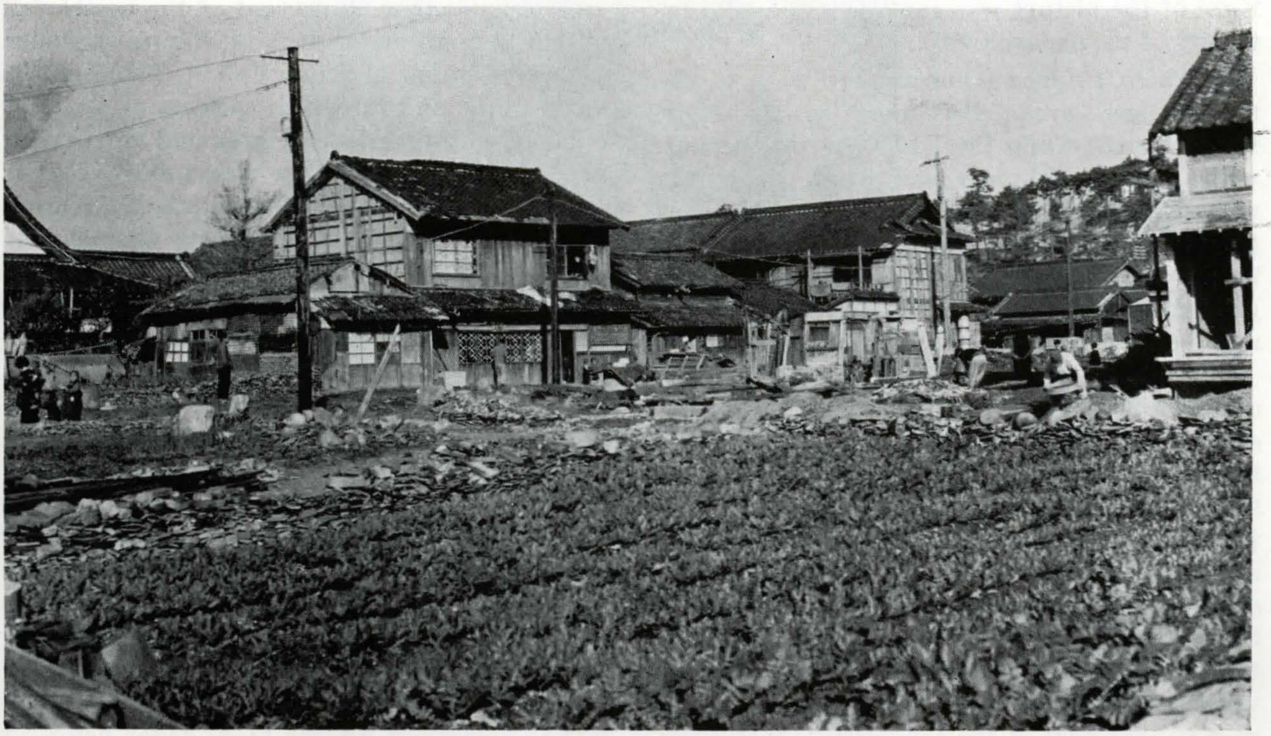


Photo 7.—Fire perimeter section, showing limit of fire damage.

spot. The left wall adjoining was also damaged by fire. Metal siding now replaces the original wood. The fire was not particularly intense at this point, so that people could approach the burning area. Two wooden electric power poles show some fire charring, which indicates a mild fire intensity.

f. Photo 8 shows some repair work on the side walls of two dwellings. The limit of the fire can be observed along the street at the left, right, and center. One dwelling unit on the far side of the street had been so badly damaged by fire that it had been torn down. Fire charring is also evident in the photo on structural timbers and on the wooden pole at the corner of the building in the center of the picture. Part of the tile-covered canopy burned by the exposure fire has been replaced.

g. Photo 9 shows the location where some 20 persons endeavored to check the spread of fire. The rear portion of the two-story, mercantile structure was torn down with the aid of long pike poles, and the fire which had attacked that building was extinguished. Re-ignition was prevented by further efforts. The defacement of the mud-and-wood treasure house wall at the right of the picture was caused by the mild intensity of the exposing fire.

h. Photo 10 shows the western edge of the fire-damaged area. Dwellings on the right were burned, while the dwellings on the left, with evidence of light repair work, occupy the undamaged half of the same block. Much of the damage has been cleaned up as is evidenced by the piles of salvage roofing tile in the foreground. The fire was fought from the ground and the interior of the standing dwellings.

i. Photo 11 shows the remaining, interior, combustible side wall of a factory. Residents stated that the radiant heat was sufficient to ignite the facing wall of the dwelling across the street shown in the middle of the picture. This facing wall was wood sheathed, as is the building at the extreme right. The exposed portions show where the sheathing was torn off during the fire. As this area is in the down-wind portion of the damaged area, bordering on the water front shown in the background, it is noteworthy that part of the combustible factory in the foreground remains undamaged. The fire at this point was fought by some 50 persons. It was from here that the first inroads were made along the western edge of the fire area by civilian fire fighters.

5. *Comment.* The foregoing examples of fire fighting demonstrated that success was achieved under the conditions which prevailed. Fire fighters availed themselves of relatively safe areas in which to operate, thereby reducing the personal-risk factor. The maximum fire-fighting effort was directed toward stopping the continued spread of the fire, lateral to the direction of wind. No effort was made to fight fires on the down-wind side of the area. Although the fire was intense and fast burning, damage was not particularly severe because only a small area was involved. As a result, fire fighters were able to approach the area and attack fire spread by tearing down burning structures.

IX. Analysis of Damage

1. *Bomb density.* The probable average bomb density in the central portion of the target has been estimated as 265 tons per square mile. This estimate is based on the reported delivered bomb load on the target area and assumes that 90 percent of the bombs fell within a limit as shown in Figure 1 under "Probable Limit of Bomb Fall." This limit of bomb fall is an oval which encloses all areas of damage within the target area and is based on ground observation at the target site. If it is assumed that a normal (Gaussian) distribution of bombs was achieved along any diameter of this oval, then it is calculated that 46 percent of the total reported delivered bomb load arrived within a central portion of the target area measured as 25 percent of the total area of the oval. This calculation results in a probable average bomb density of 448½ tons in 1.69 square miles of area or 265 tons per square mile.

2. *Appraisal of bomb density.* A bomb density of 265 tons per square mile corresponds favorably to a Circular Probable Error of 4,000 feet. A CPE (circular probable error) is a circular area of measured radius in which 50 percent of the bombs dropped are expected to arrive. A CPE of 4,000 feet has been reported by the Twentieth AF for night radar bombing with good target identification, based on photo interpretation of several target areas.

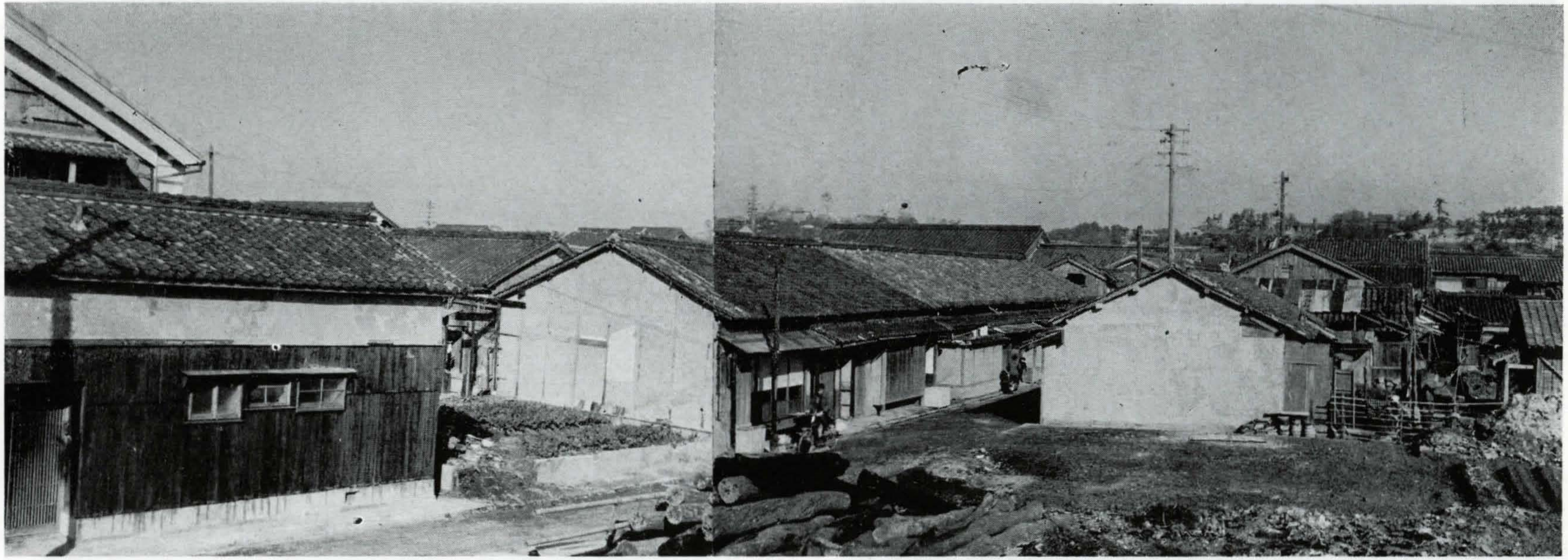


Photo 8.--Section of fire perimeter, showing partial burn-out between structures remaining intact.

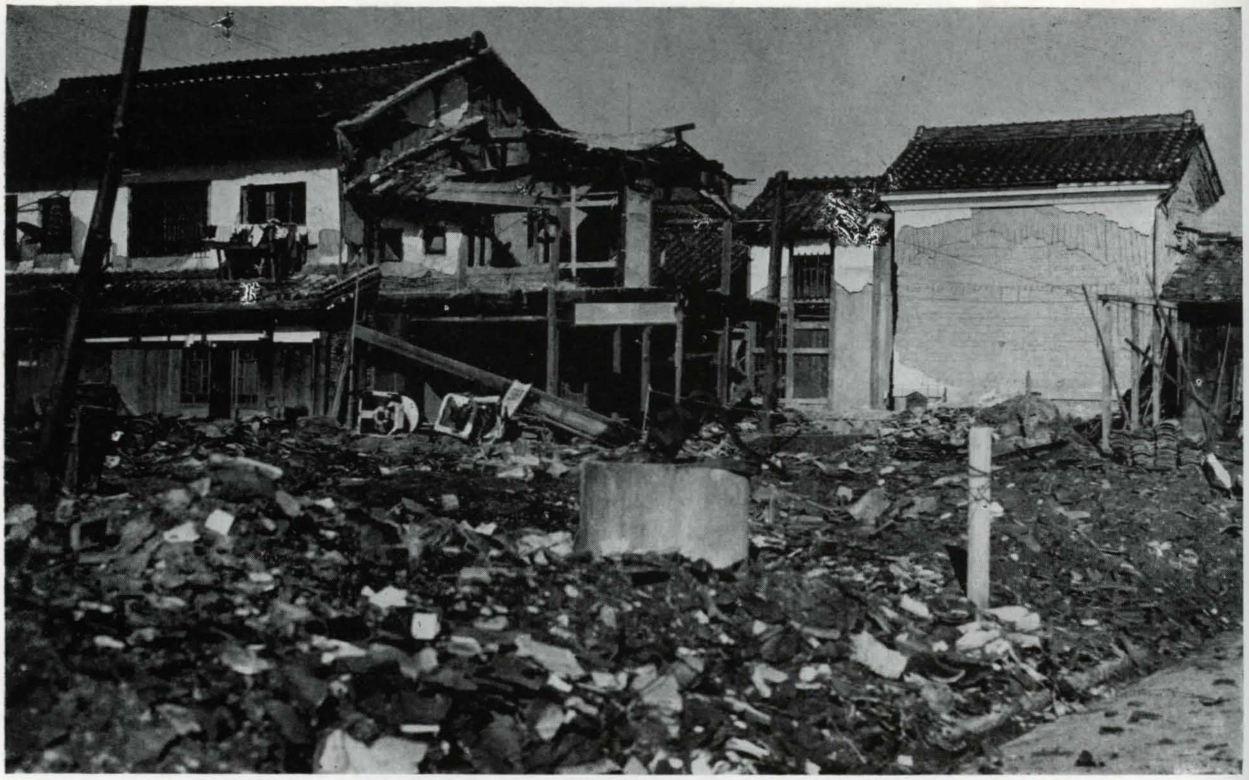


Photo 9.—Fire perimeter section showing partial fire damage to remaining buildings.

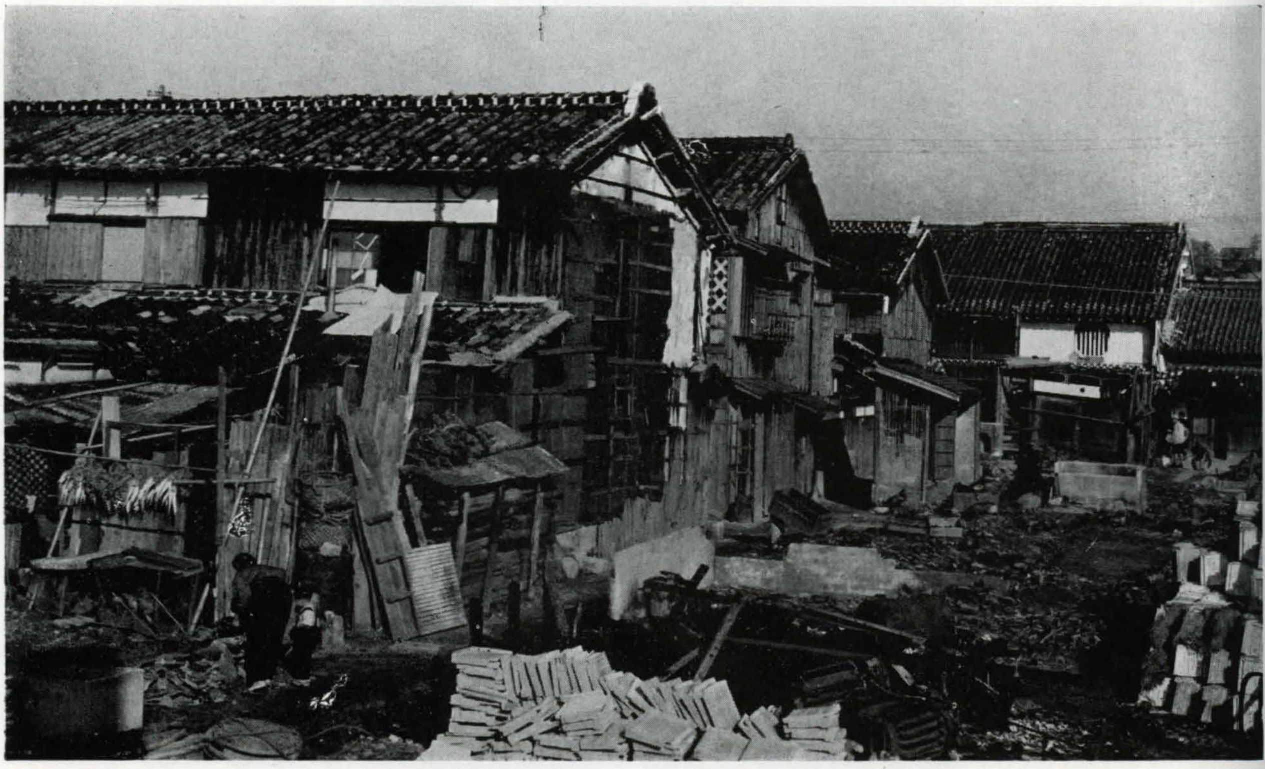


Photo 10.—Fire perimeter section showing limit of fire in middle of built-up city block.

3. *Accuracy of attack.* The planned Mean Point of Impact shown in Figure 1 is 5,600 feet from the center of the area in which the estimated maximum bomb density was achieved. The distance of 5,600 feet is too great to warrant evaluating the attack accuracy as good.

4. *Effectiveness of attack.* The amount of damage achieved by this attack is calculated as the total tons of bombs delivered (975 tons) or 0.70 acre of damage per ton of bombs reported delivered on the target. As a measure of attack effectiveness, this amount of damage sustained by the target does not appear to be commensurate with the calculated bomb density of 265 tons per square mile.

5. *Bomb penetration.* Bomb penetrations in soft earth (Photo 12) reached a maximum of 10 inches, and on asphalt-surfaced roads indentations were noted as having a maximum depth of 5 inches. In one instance, the indentations of 32 bomb strikes on a 4-inch, reinforced-concrete roof were counted. None had penetrated and the markings were merely disfigurations of the concrete surface (Photo 13). The few cases of penetration observed can not be treated statistically. The military had obliterated evidence in most cases by picking up bomb cases and otherwise disposing of malfunctioning bombs.

6. *Effectiveness of bomb.* Although over-all efficiency of an attack depends upon the bomb density delivered, and effectiveness is judged by the amount of damage sustained within the target area, nevertheless the effectiveness of an individual incendiary bomb is evaluated by its ability to ignite fires. According to eyewitnesses who were interviewed, the M69 performed this function efficiently and was therefore considered an effective weapon for its type when used against Japanese dwellings in Akashi.

7. *Damage characteristics.* Combustible structures sustained the heaviest amount of damage; noncombustible structures received varying degrees of damage, depending primarily on the combustibility of contents; and fire-resistive structures sustained only minor damage. Combustible structures within the

Photo 11.—Fire perimeter section showing building partly burned out near water front area.

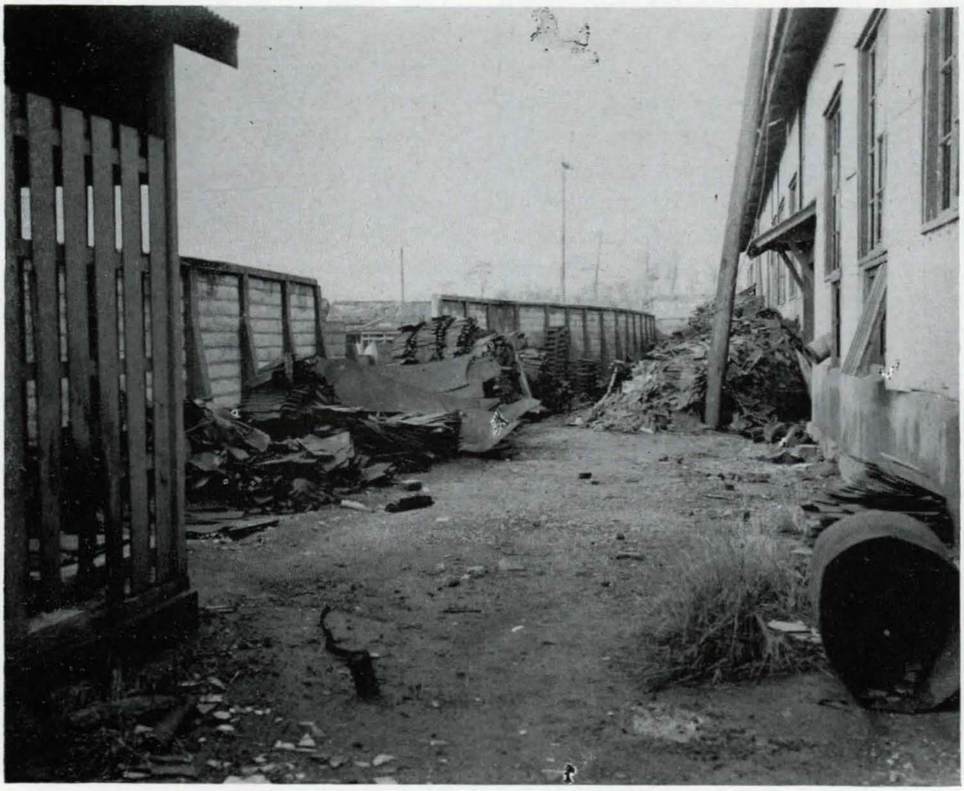


Photo 12.—Penetration of M69 in soft earth. Note case protruding from ground in foreground and minor fire damage to combustible structure, left.

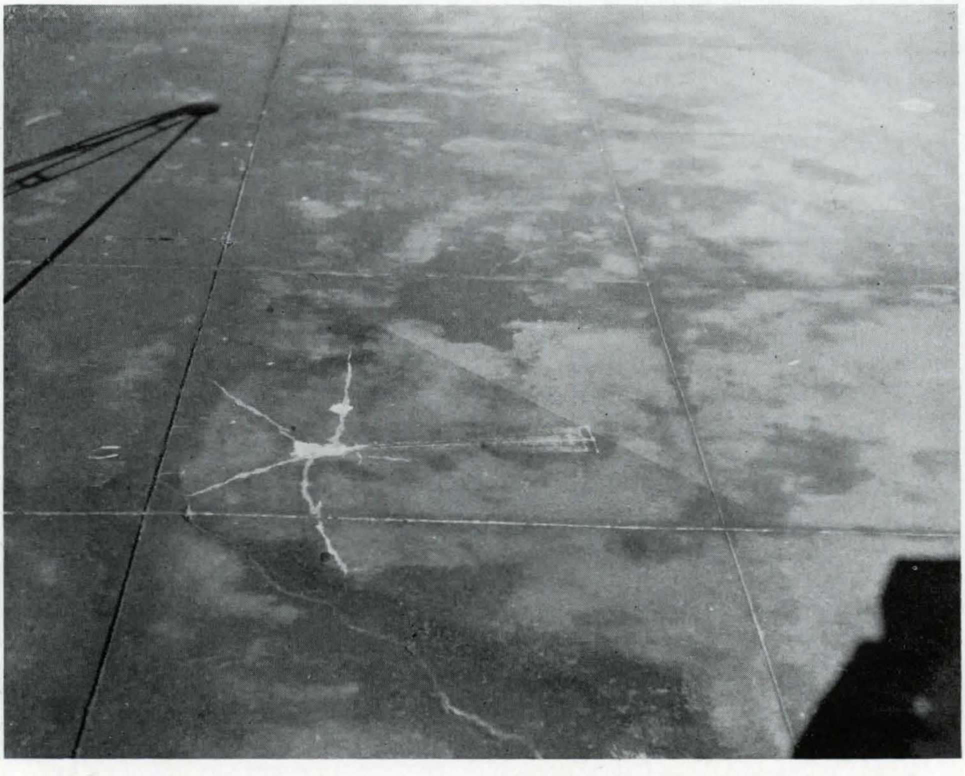


Photo 13. — Showing impact marks of M69's on concrete roof.

perimeter of fire-damaged areas were generally totally destroyed, only a few buildings being partly burned (Photos 14 and 15). The degree of damage sustained by noncombustible structures was in direct ratio to the combustibility of their contents. This damage ranged from minor, through superficial, to total structural damage as the combustibility of contents increased (Photos 16 and 17). Fire-resistive structures sustained minor damage only (internal fire damage to floors, ceilings, and trim), due to external exposure fires being transmitted through unprotected openings (Photos 18 and 19).

8. *Fire spread*

a. A study of the perimeters of all damaged areas show that fires stopped for 38 percent of the total perimeter because of varying distances of clear space in built-up areas, while, for the remaining 62 percent of the perimeter, the fire stopped because there was nothing left to burn. Fire stopped in densely built-up areas for a total of 10 percent of the perimeter; in medium built-up areas for a total of 12 percent of the perimeter; and in sparsely built-up areas for a total of 16 percent of the perimeter.

b. A study of the perimeter of the fire damage area along the leeward side as compared with the windward side shows that fires stopped on the leeward side for 76 percent of the total leeward perimeter because there was nothing left to burn, while for the same reason the fire stopped on the windward side for only 37 percent of the total windward perimeter.

c. The steady 5- to 10-mile-an-hour wind, blowing constantly during the fire was considered to have affected fire spread materially in two ways: first, the fire-fighting effort was successful in part due to the constancy of the direction of this low velocity wind, since the path of probable fire spread was easily predicted and fire-fighting efforts were, therefore, directed only toward combating the lateral spread of fire from this predicted path; and second, the effect of wind is noticeable in Figure 1, where the water front area of the eastern portion of the target is completely burned out, and, yet, up-wind and inland from this area, the burned-out areas extend into heavily built-up sections of the city along the axis of the direction of the wind. These isolated burned-out areas have not joined laterally across the direction of the wind.

d. There was no true test of either natural or man-made fire breaks in stopping fires. Fires involved all portions of respective fire divisions in the central part of the target area because the wide-spread, bomb-fall pattern rendered fire breaks ineffective. In some cases fire fighters took advantage of natural fire breaks such as streets, and fire spread was successfully stopped along streets as narrow as 15 to 30 feet.

X. Recuperability

1. At the time of the survey, the city was in about the same condition as it was immediately following the attack, with the exception of some scattered reconstruction jobs in which both new and used building materials were being used (Photo 4). Very little reconstruction work had been done on the larger public and industrial buildings (Photos 22 and 23).

2. Although the interurban electric railway was in service on a reduced schedule because of the lack of equipment, the storage yard and damaged equipment were still in the same condition at the time of the survey that they had been after the attack (Photos 24 and 25). Some work, however, had been started on clearing the yard and salvaging equipment.

XI. Conclusions and Comments

1. Fires ignited by incendiaries in small isolated areas can be successfully controlled when relatively safe areas are available for operation and maneuver of fire fighters.

2. Fire fighters can predict the direction of possible fire spread when constant-direction, low-velocity winds prevail during burning periods. Fire fighters are able to control the spread of fire in isolated burning areas along sides parallel to the direction of wind.

3. An estimated average bomb density of 265 tons per square mile on this target is ample, but suggests that a greater amount of damage per ton of bombs than calculated 0.70 acre of damage per ton should have been achieved.

4. The relatively high percentage of damage (92 percent) sustained in the sparsely built-up part of suburban Akashi (principally industrial) when compared with the relatively low percentage of total damage (47 percent)

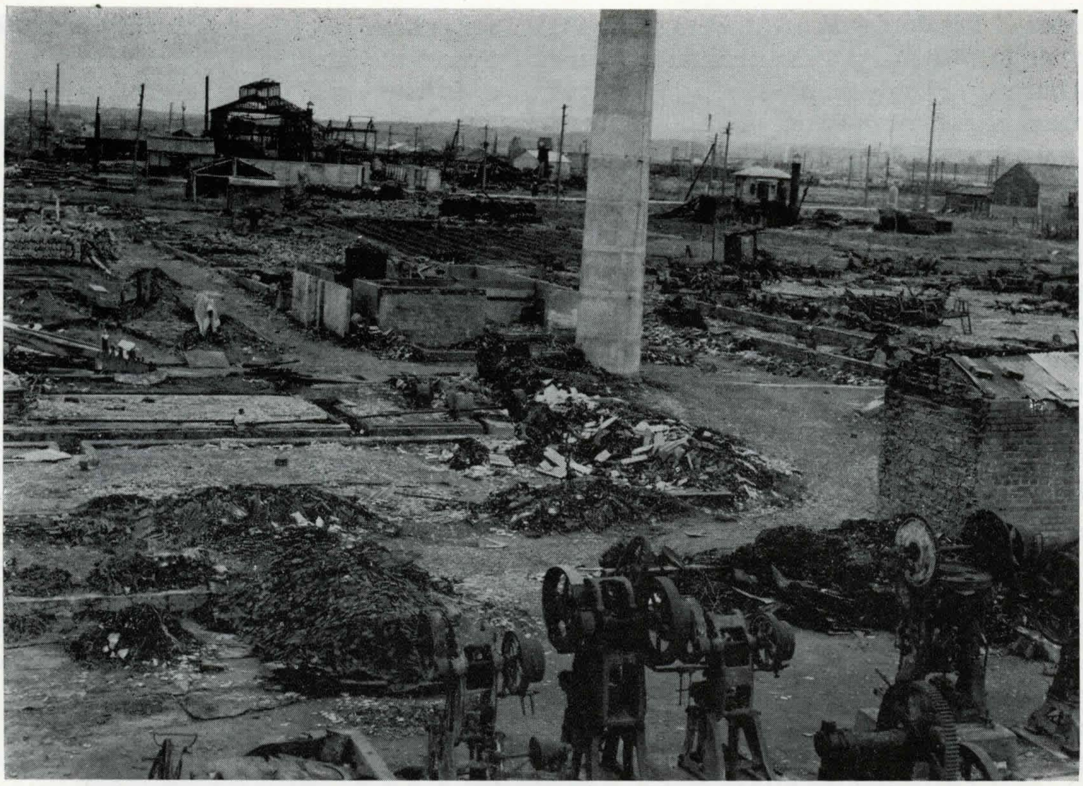


Photo 14.—Typical damage sustained by combustible industrial construction.

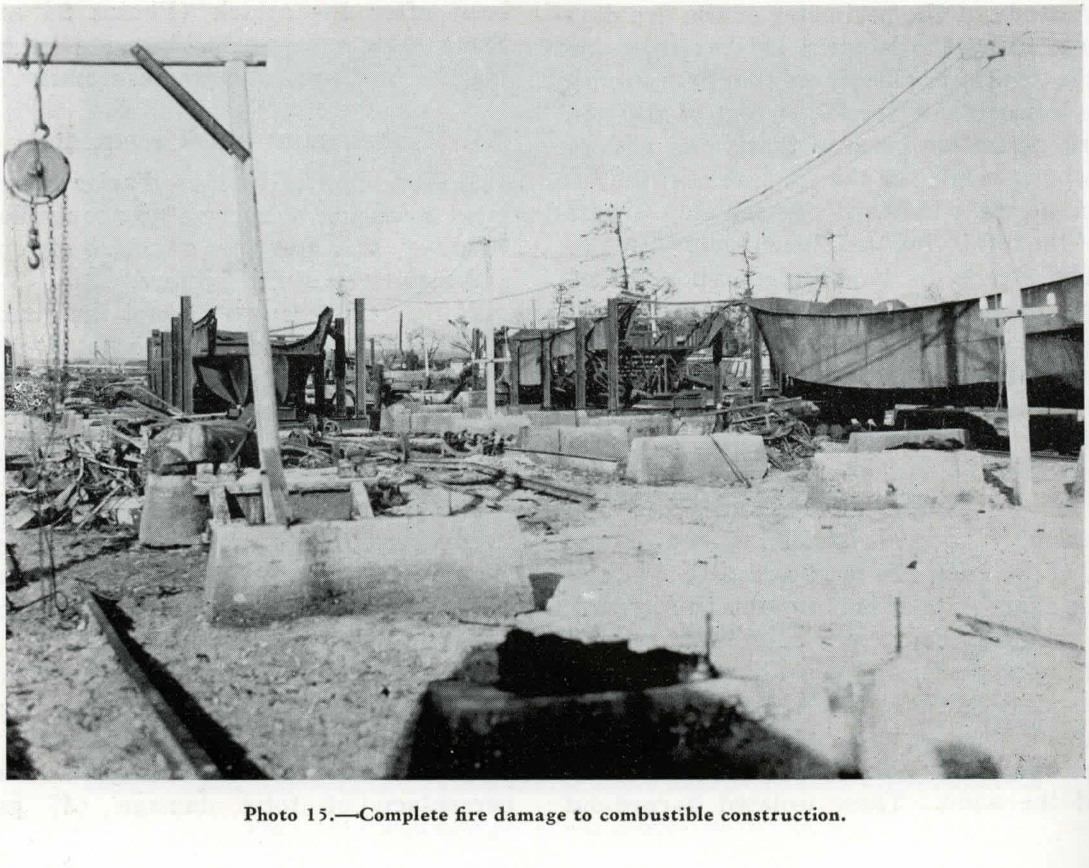


Photo 15.—Complete fire damage to combustible construction.

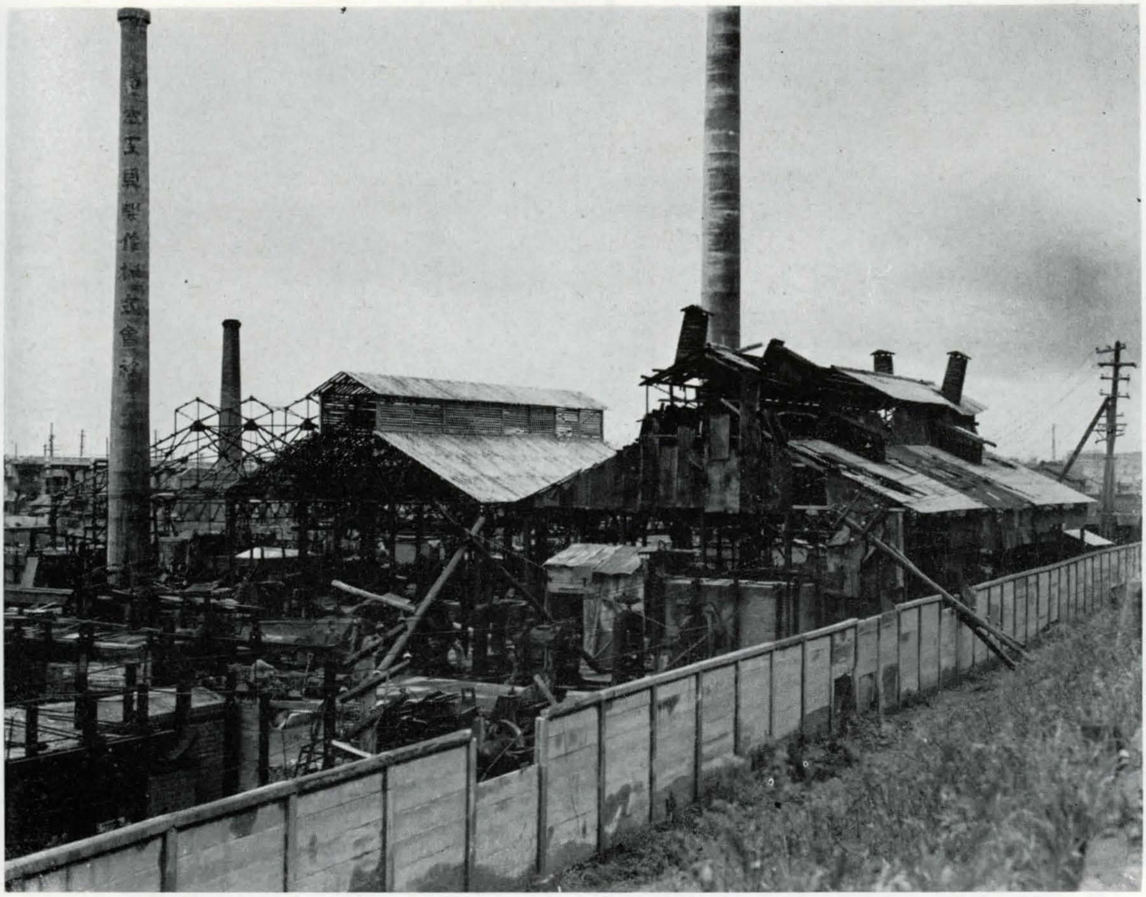


Photo 16.—Typical fire damage sustained by noncombustible structure.

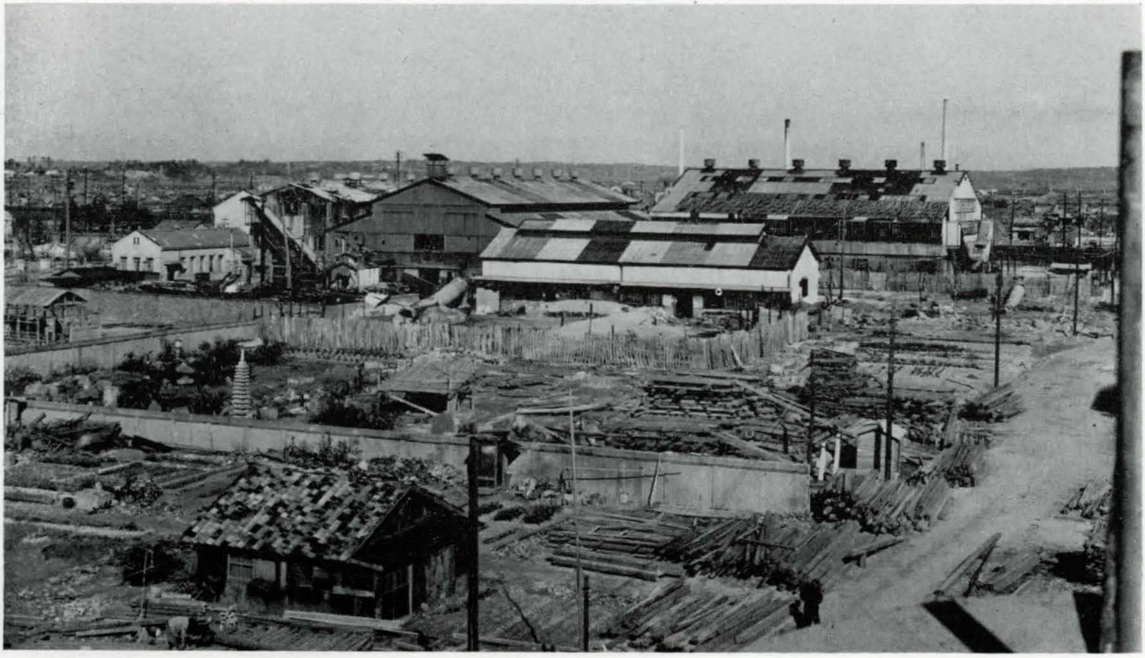


Photo 17.—Typical noncombustible construction in center of fire damaged area. Note superfiicial damage to roof.

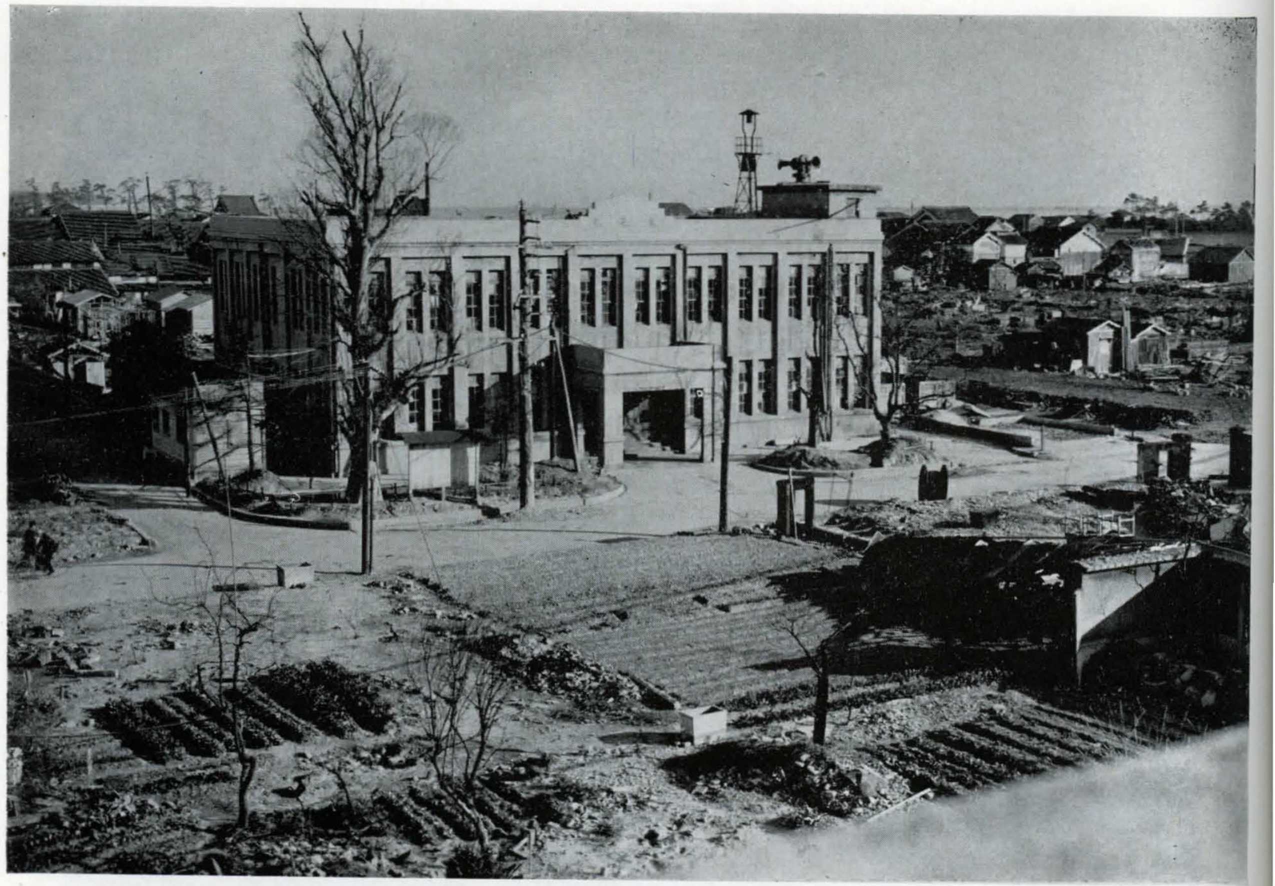


Photo 18.—Fire-resistive government building. Minor damage only was sustained in this type of structure.

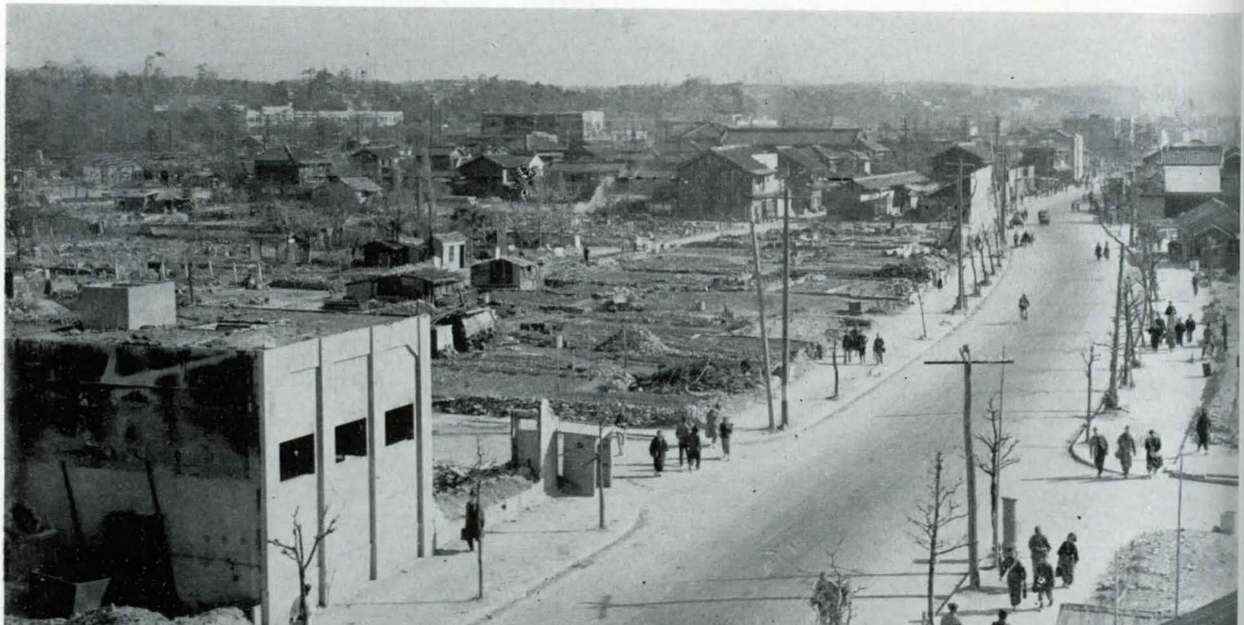


Photo 19.—Showing minor damage to fire-resistive structure in left foreground.

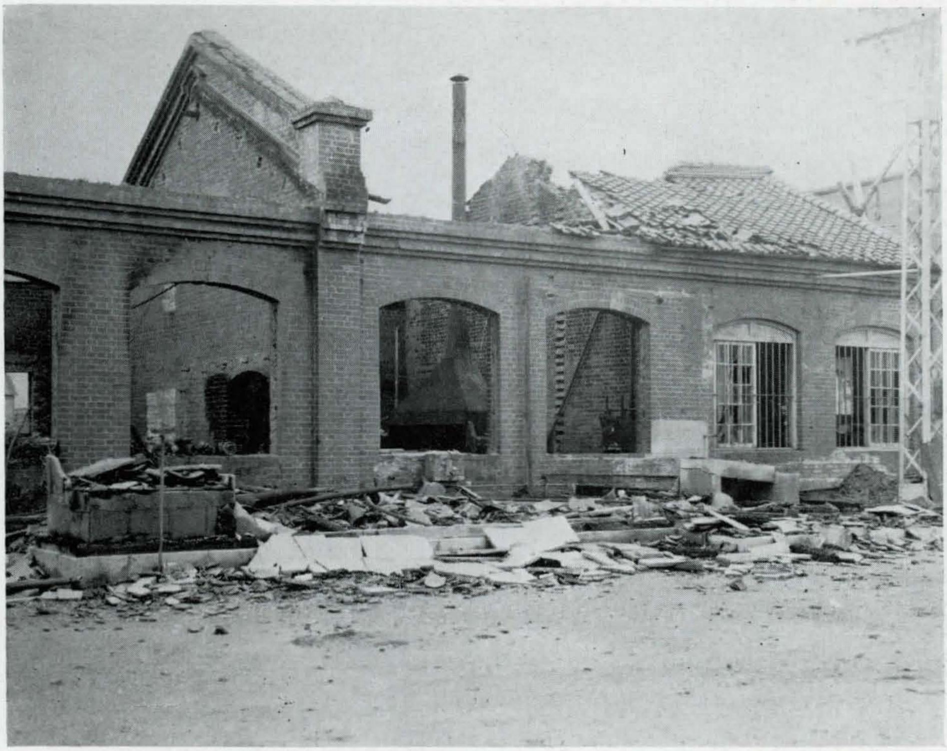


Photo 20.—Fire damage to load-bearing brick-wall structure. Note fire walls and parapets with unprotected opening.

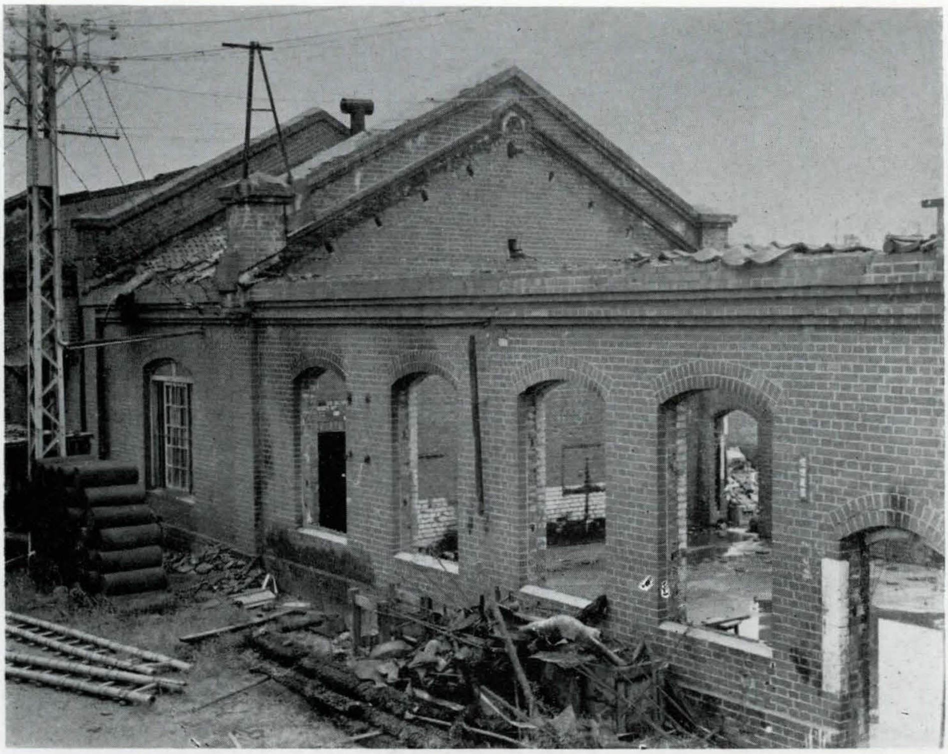


Photo 21.—Showing action of fire wall in load-bearing brick-wall structure. Fire confined to sections in foreground.

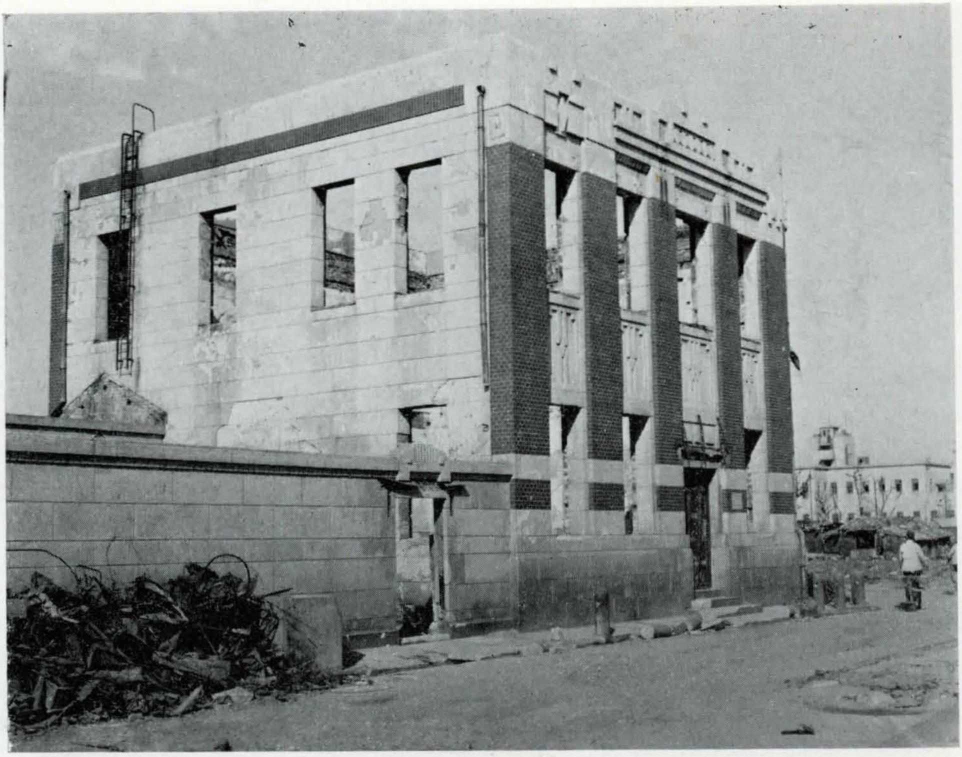


Photo 22.—Showing extent of structural fire damage to brick-wall load-bearing public building.

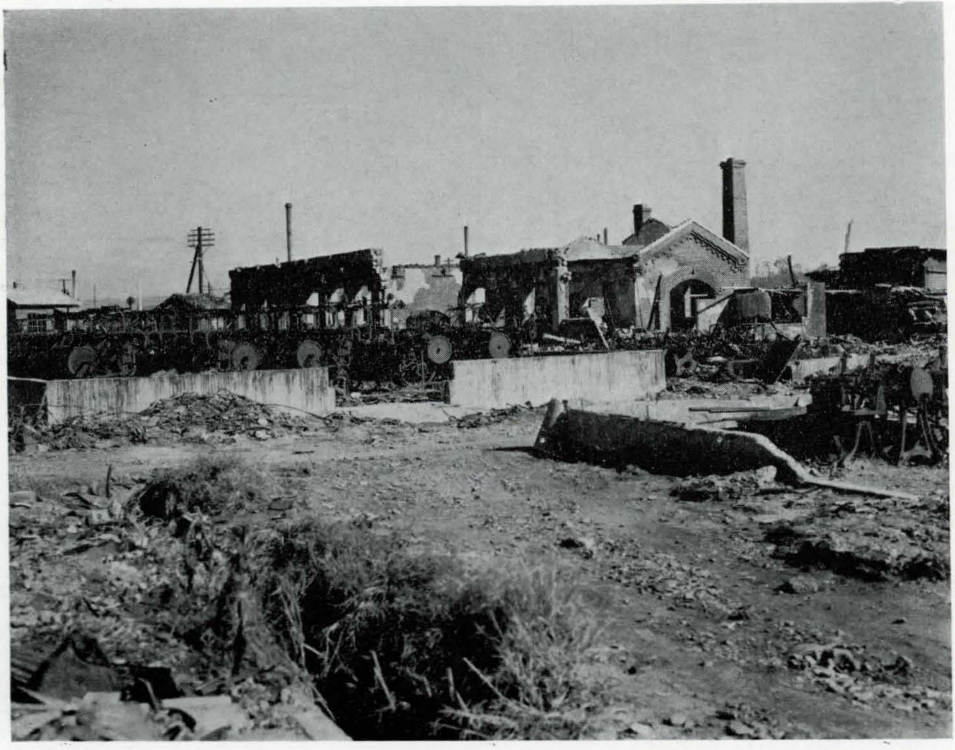


Photo 23.—Showing typical fire damage of brick-wall load-bearing industrial construction.

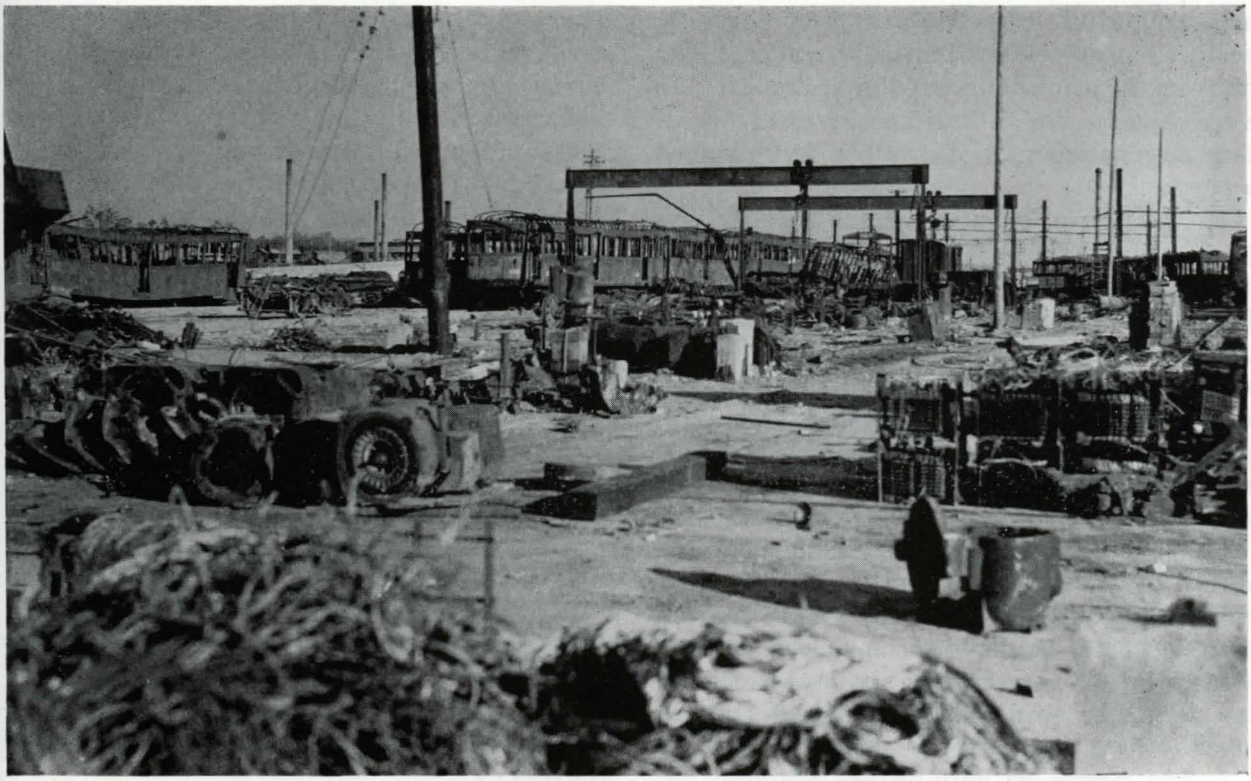


Photo 24.—Fire-damaged interurban railway storage yards.

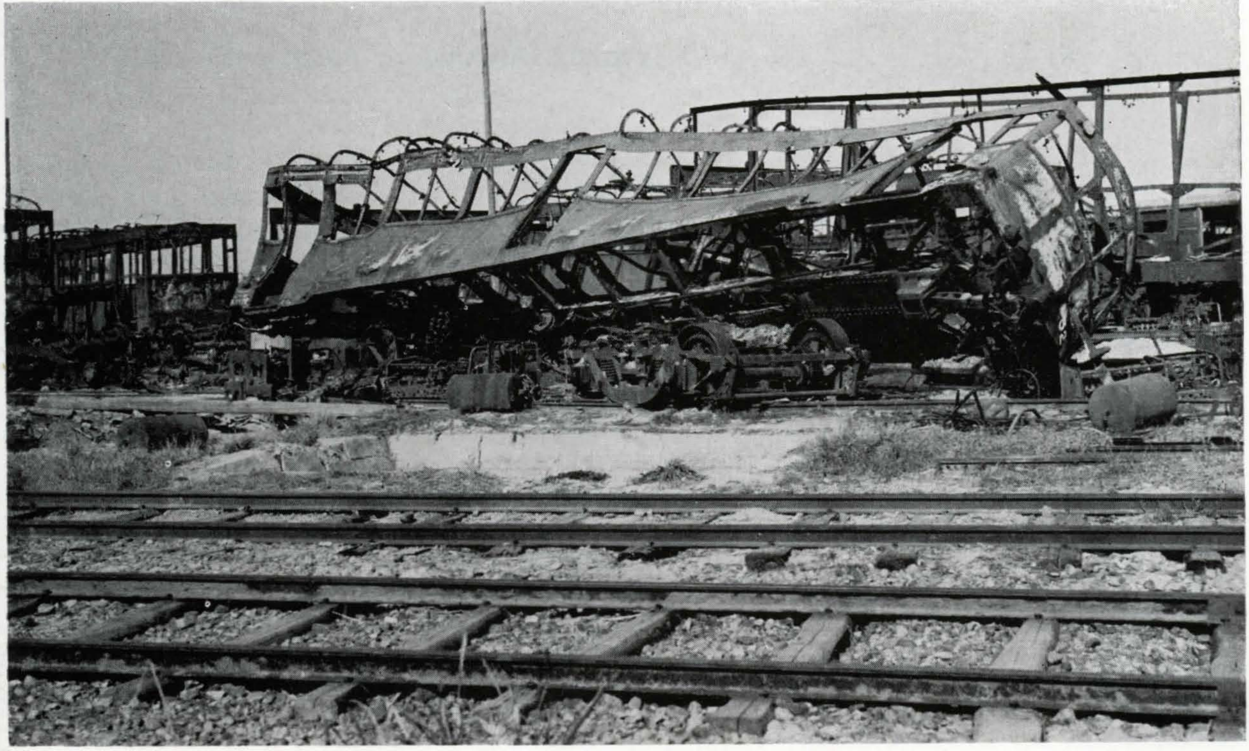


Photo 25.—Interurban railway car seriously damaged by fire.

achieved within the city suggests that the achieved mean point of impact was appreciably off from the planned mean point of impact. As a consequence, the achieved accuracy of the attack does not compare favorably with planned accuracy.

5. The lack of water in public systems was the principal reason for the failure of the fire department successfully to cope with the fire. Probably the most fortunate bomb strike was that on the electric power substation which destroyed that installation and crippled the only source of power to the city. As a consequence, the waterworks was put out of service because of its complete dependence on electrically operated pumps.

6. Wind direction definitely influences the spread of fire as was shown by the fact that only 24 percent of the leeward side of the fire area perimeter bordered on unburned built-up areas, while 63 percent of the windward side of the perimeter bordered on unburned built-up areas.

7. The degree of built-upness definitely influenced the spread of fire. Of the total fire area perimeter only 10 percent was in unburned, densely built-up areas, 12 percent in unburned, medium built-up areas and 16 percent in unburned, sparsely built-up areas. The remaining 62 percent of the perimeter bordered on open areas of clear space 100 feet or greater, or on water front areas.

8. Combustible structures, in general, burned completely; noncombustible structures sustained damage due to fire in direct ratio to the contents' combustibility; and fire-resistive structures sustained only minor damage due primarily to exposure fires transmitted through unprotected openings.

9. No true test of man-made fire breaks was noted, inasmuch as the bomb pattern was such that individual incipient-stage fires started in all fire divisions regardless of separations created by firebreaks.

10. Firebreaks were of service in some cases when used by fire fighters to stop spread of isolated fires.

APPENDICES

Page

A. Translation of Japanese Report of Attack............... 186

B. Translation of Japanese Damage Chart................ 189

Appendix A

(Translator's Note: The following is a translation of a report obtained from the Prefecture Police in Akashi.)

Military Defense Secret No. 435, 7 July 1945
Military Guard Secret No. 120
Governor of Hyogo Prefecture (Chief of Police)
(Prefectural Police and Fire Chiefs)
The Situation in Regard to Air-Raid Damage

The following is a report on the damage sustained in the air attack on this prefecture on 7 July.

A. *Enemy Air-Raid Situation.* The 60 enemy B–29's which entered the jurisdiction of this prefecture at about 0010 hours on the seventh, coming in by way of Kii Suido, Awaji, and Harima Nada, passed over the Akashi area from about 0015 to 0125 hours, flying both singly and in forty waves of five or six planes in each wave. The planes dropped a mixture of incendiary and HE bombs on the Akashi area from an altitude of 3,000 meters. After dropping their bombs, the planes passed over Harima Nada, Kii Suido, and Tokushim Ken, and finally escaped over the sea to the south.

Name of place	Time of air-raid warning	Time of air-raid alarm	Raid over	All-clear
Hyogo Ken	7 July, 1937	2303	0143	0152
Eastern Area of Inland Sea	----------	2300	0121	0144

B. *Weather conditions:*

1. Wind direction, NNE.
2. Wind velocity, 3.5 meters (7 mph).
3. Weather, rain.
4. Cloud height, clouds dense, poor visibility.

C. *Type and number of bombs dropped:*

1 About 80,000 oil incendiary bombs (large and small types mixed).

2. A few HE bombs.

D. *Damage inflicted:*

1. Imperial Household Department, none.
2. Shrines, prefecture shrines

a. Iwaya Shrine
b. Donsei Temple
c. Kaikoin Temple

3. *General damage:*

a. Casualties:

(1) Dead	115
(2) Missing	31
(3) Seriously wounded	19
(4) Slightly wounded	69
(5) Refugees	37,967

b. It is expected that all of the above figures will increase.

(Translator's Note: Reference to damage chart, Appendix "B," prepared about three days later, will indicate the justification of this assumption.)

c. Damage to Buildings:

(1) Houses,

Totally burned	9,110
Half burned	104

4. *Government and public buildings:*

Akashi Labor Mobilization Department, totally burned.

Akemi Area Office, totally burned.

Akashi Telephone Bureau, totally burned.

Akashi Post Office, totally burned.

Sanwa Bank, Akashi Branch, totally burned.

Prefecture Agriculture Experimental Station, totally burned.

City Clinic, totally burned.

Public schools (Daikan, Hayashi, Oji) three (3) schools, totally burned.

5. *Factories and institutions:*

Kawasaki Aircraft Company, Akashi Airframe Factory, totally burned except for six buildings. However, the dispersal of the machinery and equipment had been 95 percent completed.

Kawasaki Aircraft Company, Akashi Ordnance Works, 5 of the 10 buildings were totally burned. However, the dispersal of the machinery and equipment had been 50 percent completed.

Kawasaki Vehicle and Boat Factory, 18 out of the 18 buildings were totally burned.

Japan Tool Company, Factory No. 123, 9 out of 10 buildings were totally burned. However, six machines were saved by dispersal to other plants.

Kinoshita Iron Foundry, Main Factory, one part was totally burned.

Takashimaya, Ida factory, eight out of eight buildings were totally burned.

Kishiro factory, totally burned.

Akashi Engine Factory, one out of one building was totally burned.

Nichiryo Steel Works, three out of four buildings were totally burned.

Japan Warehouse, Warehouse No. 1, four out of five buildings were totally burned. Materials in the buildings (dried cocoons, 5,555 tons; army medical supplies; raw rubber; army clothing) 85 percent burned.

Osaka Gas Co., Akashi Plant, six out of six buildings totally burned.

Sanyo Electric Railroad Co., Akashi Vehicle Factory, totally burned.

6. *Transportation facilities:*

Government Railroad Lines, Akashi Station, thirty articles of small freight burned.

West Akashi Station, six buildings were totally burned and one building was half burned. Two passenger cars and two freight cars were totally burned. Between Akashi and West Akashi Station, 277 railroad ties were burned. Wires were cut and down at two places. Because of this, street car and train service was interrupted for 1 hour. However, street car service to the east of Akashi was resumed at 1200 hours the same day and service in western Akashi and to the west was resumed at 1400 hours. The trains were also able to run by 1400 hours.

(Translator's Note: Power to operate the railway was obtained from Osaka through the railway's own substations which were not damaged.)

Sanyo Electric Railroad, The Akashi Car Factory, Akashi Operations Office, and the Akashi Switch Station were completely burned. Twenty-one passenger cars, 10 freight cars, and 1,337 railroad ties were also burned.

Extent of service:

Nishi Maiko to Hayashizaki, disrupted.

Hyogo to Nishi Maiko, in operation.

Hayashizaki to Himeji, in operation.

It is expected that all lines will be reopened on the ninth.

7. *Communication facilities:*

Akashi Telephone Bureau, completely burned, and telephone poles and wires were cut and destroyed. Recovery will take some time.

8. *Gas, water works, electricity:*

a. Gas: Because the Akashi Branch of the Osaka Gas Co. was completely burned, it is impossible to supply gas to the entire area and the time of recovery is uncertain.

b. Water works: The pumping station and the main pipe lines were not damaged. However, only 90 percent of the total water supply can be expected due to the damage to the water systems in the various houses. At present, it is impossible to pump the water to the reservoirs because of the stoppage of electricity. The damage done to the water systems of the various houses has caused leaks and, therefore, reduced the water pressure. The restoration of the water supply and equipment of the houses is uncertain. With the restoration of electric power, however, the water supply system will be restored.

c. Electricity: The Akashi Power Station of the Kansai Electric Co. and the Akashi Power Control Station were completely burned. Power lines at various places within the city were cut. A quick recovery is not anticipated.

E. *Relief:*

1. *Medical relief.* Adequate aid was extended to the nine relief stations which were burned and to the victims of the attack. Because the relief stations at both the Akashi and Hitomaru public schools were in good condition, they were able to take in the light and heavy casualties. Gradually help arrived. The relief units of the Himeji Army Hospital Relief Squad and of Tansu, Mayor of Kobe, totalled 90 men and carried out treatment of the injured.

2. *Food rations and other aid.* Camps for the air-raid victims were established at the Girls' Normal school, the Tamatsu No. 1 and No. 2 schools, and the Akashi Fujie and Toba public schools. Five thousand breakfasts were distributed and the distribution of the noon and evening meals was as follows:

	Meals
a. Mikage Police Station	5,000
b. Kakogawa Police Station	10,000
c. Nishiwaki Police Station	20,000
d. Takasago Police Station	30,000
e. Hayashi Police Station	10,000
f. Suma Police Station	10,000
g. Miki Police Station	10,000

h. One thousand portions of dried bread were distributed from the Akashi Police Station.

i. A total of 96,000 meals was given out.

Furthermore, not only was bedding supplied by the Municipal Office, but two truckloads of bedding were received from Kobe. It is expected that Akashi will receive the utmost in help. Moreover, the Chief of Police of Iwaya is giving an adequate amount of food and help to the victims who took refuge in small boats along the coastal area of Awaji and Iwaya.

F. *The situation in regard to public order.* As has been customary in various cities recently, a portion of the people fled when the warning was issued, but the majority of the people remained and courageously fought the fires. In the early stages remarkable results were achieved everywhere against the many waves of incendiary attacks, but, during successive attacks, the scarcity of water increased. This, together with the fact that those fighting the fire became fatigued, made things very difficult. The fact that the damage stated above occurred, though unavoidable, is regrettable.

The most important problem today in regard to aiding the sufferers is the housing problem. Simple houses are being constructed in the northern part of Akashi by utilizing old lumber. The measures called for by the chief of police were speedily carried out directly after the attack, and were supplemented by strenuous efforts of relief agencies. In spite of the fact that 70 percent of the entire population suffered from burns, public peace in general has been maintained and at present there is no reason to be especially concerned on this score.

The construction of all types of important factories in the suburbs necessitated the construction of dwellings due to the influx of laborers. Adequate steps to help these sufferers not only bear an important relation to production, but their influence also extends to public peace. This fact is fully appreciated and everything possible is being done.

G. *Miscellaneous items:*

1. *Activities of the police and fire officials:*

a. Police. One policeman who was in charge of a certain area in the vicinity of the Nishishin Machi Branch Police Station courageously carried out air-raid defense duties. Not only did he work with an air-raid defense group and handle buckets of water himself, but he also encouraged the victims who happened to be there too. By soliciting their cooperation he was finally able to put out a fire. Just before the warehouse of the food managing commission at Nishishin Machi, Go Chome, burned, the police chief, who was the defense commander of a small area, shouted to the people near by, "Everybody must help carry the sacks of rice out of the warehouse because those who do not help will not receive any food rations." At the same time, he quickly rushed into the warehouse. The people in the vicinity, who had, up until that time, stood idly by as mere spectators, followed him and cooperated in carrying out the rice sacks. In this manner, all of the 50 sacks which were in the warehouse were saved from burning.

b. Firemen. As soon as the warning was issued, the fire engines were dispersed to their stations according to a fixed plan. Then, when fire occurred, the fire-engine crews carried out their duties well in the face of successive waves of attacks and, without moving from their position, succeeded in generally extinguishing even the large fires. Moreover, during these operations, one fireman was seriously wounded.

2. *The influence of the attack on production.* As has been stated before, the dispersal of the machinery and equipment belonging to the Akashi Plant of the Kawasaki Aircraft Co., the Akashi Ordnance Plant of the Kawasaki Aircraft Co., the Akashi Plant of the Kawanishi Engine Works, and other important factories which were damaged had been generally completed. Because of this, the damage done to them was not very great. However, the fact that the Akashi Power Substation of the Kansai Electric Co., and the Akashi Gas Producer of the Osaka Gas Co. which was in the process of recovery after being bombed in the raid of 22 June were totally burned, seriously hindered the flow of supplies to the Kawanishi Engine Works and the Nishi Okubo Plant of the Kobe Steel Co. which are located in the suburbs of Akashi. Also, the universal damage to the medium and small subsidiary plants, which was closely interrelated with the injuries to the workers, had a great influence on production.

APPENDIX B

Report on Damage Received From Bombing, Akashi City

Population before the air attacks	84,010
Number of houses before the air attacks	17,973

Date	Attack	Dead	Seriously injured	Slightly injured	Number of houses totally damaged	Number of houses partly damaged	Number of houses slightly damaged
19 January	1	300	69	118	135	258	482
9 June	2	642	248	345	1,226	2,158	----------
22 June	3	25	22	32	175	373	232
26 June	4	142	66	141	357	1,093	----------
7 July [1]	5	355	57	133	9,075	104	----------
Total	----------	1,464	462	769	10,968	3,986	714

Number of houses in poor condition	1,000
Number of persons who live in houses which are in poor condition	4,500
Number of persons who remain in houses which are in poor condition	3,000
Number of houses at present (including those which are partly destroyed)	7,005
Population at present (it is estimated that about 25,000 persons have moved outside the city)	81,401
Number of houses remaining	6,005
Number of persons remaining	56,401

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[1] This chart does not include 31 persons listed as missing as the result of this attack.

EDITOR'S NOTES: (1) This table is a translation of the Japanese summary. (2) The first four attacks listed on the above chart were HE attacks directed against the Kawasaki Aircraft Plant. See Physical Damage Report 72.

Part 6

EFFECTS OF INCENDIARY BOMB ATTACK ON HACHIOJI, JAPAN

Dates of Survey: 23 November — 1 December 1945

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 192

II. SUMMARY 192

III. GENERAL INFORMATION 192

IV. THE TARGET 193

V. THE ATTACK 194

VI. FIRE DEFENSE DATA 195

VII. FIRE DAMAGE AND CASUALTIES 196

VIII. ANALYSIS OF DATA 197

IX. CONCLUSIONS 207

X. APPENDICES (Figures 1–3, inclusive) 207

Photographs 1–14, inclusive

I. Object of Study

1. The primary objective of this study was to ascertain the effectiveness of M50 (4-pound magnesium) incendiary bombs in setting fires to Japanese domestic structures and penetrating heavy concrete roofs. The M50 bomb was developed primarily for German-type dwellings and industrial plants where good penetration was required, and, except in a Navy attack on Naha City, Okinawa, had never before been used on a Japanese city subjected to only one attack.

2. The secondary objective was to determine the degree to which air-raid precautions and extent of damage were affected by the practice of warning the inhabitants in advance of an impending air attack.

II. Summary

1. Hachioji was located along a flat river plain 23 miles west of Tokyo. It had a normal population of 45,000 which had increased to 68,000 with Tokyo refugees. The city was oval in shape, covering two square miles, of which 1.4 square miles was well built up. Its only prominent land marks were Mt. Fujiyama and the Yudone River, both of which were used for visual location checks by the pilots. The city was fairly modern, having electric railways, a few wide streets, and modern utilities, but only four small, modern, reinforced-concrete buildings.

2. Industrially, economically, militarily, and commercially the city was unimportant, except for being a railroad junction and a refugee center for Tokyo. The city was highly combustible and vulnerable yet had made no major preparations for its defense. An unusual condition was injected into the picture by the presence of fifty additional fire trucks dispatched eight hours before the attack from Tokyo because of the Twentieth AF pre-attack warning.

3. A total of 1,593 tons of incendiaries (95 percent M17 clusters) was dropped on Hachioji as a primary target on the night of 1/2 August 1945. One hundred and sixty-eight B–29s bombed both by radar and visually from an altitude of 14,000 to 16,000 feet. It is estimated that 200 to 300 tons per square mile fell on the burned city area and the remainder within a 3-mile radius of the city. There were neither previous nor later attacks on the city.

4. The fire damage involved 15,334 buildings in the city and its suburbs and included every industrial and public building, except two banks, one school, and the telephone exchange. Three hundred and five persons were killed and 792 were injured. The area of damage was 0.95 of a square mile in the city, or 68 percent of the built-up portion, and 0.2 of a square mile in the suburbs. The remaining unburned buildings were mainly on the south edge, or windward side, where no bombs fell.

5. The fire defense was strong, consisting of the largest known number of firemen and pieces of equipment per square mile ever gathered to fight a conflagration started by air attack, but training of the people had been poorly carried out and there had been no organized practice. The results of the attack might have been much different, if the water supply system had been undamaged, since the fire reached conflagration proportions only after the water supply failed.

6. An attempt was made to establish the chance of fire spread on the windward and leeward sides at various exposure distances. The results showed a total of 25 percent fire spread which varied with the direction of the wind. The probability of fire spread was found to be about 20 percent on the leeward side and five percent on the windward side with a light breeze blowing (5 to 10 miles per hour). The chance of fire spread across an open space varied from about 70 percent at 25 feet to 40 percent at 75 feet on the windward side, compared to 90 percent and 50 percent for the same distances on the leeward side.

7. The penetration of the M50 bomb was checked by measuring the depths of 34 hits on four concrete roofs. The deepest was 5 inches, the average 1.5 inches; none perforated any of the four roofs (minimum thickness six inches).

8. The Mean Point of Impact was found to be only 715 feet from the aiming point, and the estimated Circular Probable Error was between 4,000 and 5,000 feet.

III. General Information

1. This survey was conducted by Maj. F. J. Sanborn, fire and incendiary-bomb specialist, with the assistance of Cpl. Tyshine and Mr. M. Hall, language interpreter, from 22 November

through 1 December 1945. The target had been hit only once, less than three months before the survey, and was in excellent condition for study. The Hachioji police, firemen, mayor, school superintendent, water-works superintendent and others were interrogated and all were helpful and appeared sincere. The fire chief assisted several times in the study, being intrigued by the development of the "fire spread factor" and "exposure distances." Time did not permit complete studies of damage to all types of structures or equipment, but some observations were made concerning them.

2. A fire damage map (Figure 1) of the city was prepared, showing the perimeter of the damage. Another map (Figure 2) of scattered, suburban, burned areas was prepared by the Hachioji Police Department and spot checked by the survey team. The locations on Figure 2 are approximately correct but the size and shape of the burned areas were not checked. The exact location of the point of fall of many bombs inside the burned area was determined by hunting through the paved streets for evidence of bombs scars.

3. Pre- and post-attack photographs were of too poor quality to permit any appraisal of the accuracy of photo interpretation.

IV. The Target

1. *General.* The city of Hachioji was located along a flat river plain, 23 miles west of the imperial palace at Tokyo and only five miles from Tachikawa. It was the first city west of Tokyo en route to Mt. Fuji. Its normal population was 45,000, but, owing to the numerous fire attacks on Tokyo, the city's population had been gradually increased to 68,000 by Tokyo refugees. The city was not modern by Tokyo standards as it had no large reinforced-concrete buildings, but it did have many wooden commercial shops with modern fronts and trim. The city covered more than two square miles of which 1.4 square miles was 20 percent or more built up.

2. *Industry.* Industrially, Hachioji was not important in the Japanese economic system. It was a railway junction for lines entering Tokyo from the north and for a branch line to Nagoya. The main manufacturing was silk weaving, some of which was being processed for military use. None of the textile plants had been converted to wartime products. Unknown to United States Intelligence at the time, one of the largest underground factories in Japan was being completed in the hills of Hachioji for the assembly of airplanes. Most of the workmen, however, were to come from outside Hachioji.

3. *Military.* At the time of the attack, this city was of little military importance. It housed no troops, had no warehouses, was not a shipping center, had no airfield and had only six antiaircraft guns. It was probably chosen for attack because of its proximity to Tokyo and its value for housing Tokyo refugees.

4. *Structures*

a. General. The non-industrial buildings, mainly one- and two-story dwellings, arranged in compact rows with eaves nearly touching, were much like those of other cities of its size. There were no barrack-type dwellings because of the absence of large corporations. Shrines were frequently found in local beauty spots, and gardens and cemeteries were spotted throughout the city. The main street and two parallel streets were apparently mercantile for all three were studded with burned and unburned "godowns" (vaults), safes, and damaged merchandise. Small home shops, in which was performed wood and iron work by hand or light machinery, were also common.

b. Domestic and home shops. The residential area that surrounded the commercial core was composed of typical Japanese one- and two-story dwellings without basements. They had wooden foundations set 1½ feet above ground, ½-inch wood floors covered with tatami mats, ¼-inch wood ceilings, tile on wood (mud fill) roofs and mud on bamboo lath walls. The two-story structures had open stairways, and inner partitions formed by either thin plaster or wood sliding doors. Dwellings were distinguished in size by the number of 3- by 6-foot mats in a room. Families averaged five members and houses averaged 500 square feet in plan area. Heating was entirely by braziers. Shops in the home were fairly common, being used for making wooden baskets, tubs, and shoes; for tailoring and various kinds of repairing; and for producing other articles that can be made by hand from wood or metal.

c. Commercial structures. As far as could be ascertained, all the commercial structures were wood frame. Many of the better ones had glazed tile, stucco, or imitation stone fronts. A few structures had sheet iron over wood side walls to reduce the fire exposure. "Dozo" constructed vaults, known as "godowns," were unusually common. Usually, the "godown" roof was of frame construction covered with extra-thick mud. The walls were also built of mud. Iron doors and window shutters protected wall openings. In general, the small mercantile stores compared in interior combustibility with United States variety stores that deal in fabric novelties and household furnishings.

d. Manufacturing structures. Every manufacturing building had wood-frame construction. Even though asbestos and sheet-iron sheathing were frequently used, the framing was wood. As a result, every industrial plant in the city suffered fire damage.

5. *Utilities.* The city had its own water system, an electric rail line across the city with two stations, adequate electric power, a small gas-manufacturing plant, telephones, and a sewage system. The electric power came in from a single outside source to a central transformer and switch station. Wood poles were used to support power and telephone lines.

6. *Vulnerability of the city*

a. Built-upness. Because of the lack of good quality pre-attack photographs, it was impossible accurately to determine the built-upness of Hachioji. Judging, however, from photographs and an inspection of the burned area, the city was closely built up with no large parks, rivers or similar open areas in the central section. The Twentieth AF considered 1.4 square miles adequately built up (20 percent or more) for an all-incendiary attack. On the average, the center of a typical Japanese city contains about 10,000 families per square mile, but in Hachioji, 12,000 families were dehoused per square mile. It is, therefore, estimated that at least ½ square mile was 40 percent built up; another ½ square mile, 30 percent, and a third ½ square mile, 20 percent.

b. Combustibility. Nearly every building was of combustible construction, providing practically a continuous source of combustible material without interruption by fire-resistive structures. Man-made firebreaks had not been constructed, since city officials considered their city too small to be chosen for attack. The only physical hindrance to the spread of fire was the natural width of streets and, as in other Japanese cities, there were but few wide streets in the city. The fire vulnerability must have been at least equal to that of other cities of its size.

7. *Pre-attack warning and preparations.* Thirty hours prior to the attack, the Twentieth AF radio announced the names of 12 Japanese cities, one of which was Hachioji, that were to be bombed. Fifteen hours before the attack, warning leaflets were dropped two miles from the city. The radio continued to announce the Twentieth AF warning hourly. City officials reacted quickly by telling the citizens that all able-bodied men should say in the city, but that women and children could go to the near-by hills. City officials estimate that some 12,000 people left that day. About the time the B–29 planes left their airstrips, the city of Tokyo sent 50 of its largest pumper-type fire trucks and 300 professional firemen to assist the local fire department, if necessary. By 5 o'clock that afternoon all the equipment had arrived and had been stationed at strategic locations.

V. The Attack

1. The city had never been bombed prior to 2 August 1945. The Twentieth AF records show that on Mission 306, on 1–2 August 1945, 180 B–29s of the 58th Wing were dispatched to bomb Hachioji as the primary target. Twelve planes carried 75.9 tons of M47 incendiaries (including one M47 white phosphorus), and 168 planes carried 1,643.5 tons of M17 clusters. Eleven planes dropped 68.8 tons of M47s and 158 planes dropped 1,524.5 tons of M17 clusters over the city. Ninety-seven planes bombed visually and 72 bombed by radar between 0145 and 0329 hours through $\frac{5}{10}$ to $\frac{10}{10}$ clouds at an altitude of 14,800 to 16,000 feet. The axis of attack was between 19° and 62°, this being chosen perpendicular to the long axis of the city to take advantage of the azimuth errors. The aiming point was selected in the center of the city, northwest of the railroad yard. Enemy interference was slight, only six enemy planes

counter-attacking. The execution of the attack was considered normal.

2. *Bomb types.* The M50 incendiary bomb is a 3.7-pound magnesium bomb designed primarily for German-type domestic structures. It is carried in M17 clusters, each holding 110 bombs, the weight being 475 pounds per cluster. The M47 bomb is an oil-gel-fill bomb in a metal casing that weighs 69 pounds filled, and has an instantaneous nose fuze. It is often clustered in a T19 cluster adapter holding five or six bombs.

VI. Fire Defense Data

1. *Civilian participation in defense.* The people were poorly trained and disciplined. City officials had never expected an attack on Hachioji and had not prepared for it. Early in the war, the people had been trained to extinguish the thermite bomb, and later the M50 (four-pound magnesium M54) bomb by using sand. Still later, the use of water instead of sand had been stressed, as the majority of the incendiaries dropped on near-by Tokyo had been oil bombs. Some 12,000 people fled the city, so it cannot be assumed that every dwelling had someone to defend it. Nevertheless, since the city had 23,000 refugees, there was at least more than the average of five persons per house. Interrogations showed that many of the people stayed in their homes until the fire situation became hopeless. Individual fire fighting was most evident along the windward side of the city. An estimated 300 hand pumps and small, concrete, water tanks were available for the use of residents.

2. *Fire department.* The city of Hachioji had the following men and equipment with which to combat fires:

a. 15 500-gpm pumper trucks.
b. 11 250-gpm pumper trucks.
c. 4 150-gpm pumper trucks.
d. 700 lengths (60 feet each) of fire hose.
e. 156 full-time paid firemen.
f. 60 volunteers (partly trained).
g. 330 hydrants distributed throughout the city.
h. 50 500-gpm pumpers and hose with 300 experienced firemen from Tokyo.

3. *Water supply.* The water supply consisted of a filled 2,750,000-gallon reservoir on a hill, giving a normal static pressure of 50 pounds per square inch. Three electrically driven pumps, each having a 2,000-gallon-per-minute capacity, took suction from the river and were arranged to pump to the reservoir or directly into the system. The water-main pipe sizes varied from 3 to 16 inches. (Location and size of main feeders are shown on Figure 1.) One man was kept at the pumping station to start the pumps as required. In addition, the Yudone River running the entire length of the north side was a source of water for some portable equipment.

4. *How the fire was fought.* It had rained two days before the attack, but thereafter the weather had been clear. A light breeze reported by the Japanese at 5 to 10 miles per hour was blowing from the southwest. Clouds covered about half the sky. The Tokyo fire trucks had been distributed around the city at strategic locations chosen by the Hachioji fire chief. All the Hachioji firemen had been alerted and the equipment made ready to roll. The greatest known concentration of men and equipment (50 fire trucks per square mile) ever gathered to fight a fire in any of the Japanese urban attacks were ready and waiting. Tentative plans had been made as to where the equipment would be relocated in the event any one section was bombed first, and flare signals had been adopted for intercommunication be-

TABLE 1.—BOMB AND TACTICS DATA

Mission number	Date	Air force	Primary target	Planes dispatched	Time	Number planes bombing		Altitude of release	Visibility	Plane loads released	Type bomb	Tons of bombs released	Number of bombs clusters)	Intervalometer spacing
						Visual	Radar							
								Feet						*Feet*
306	2 Aug. 1945.	Twentieth AF; 58th Wing	City of Hachioji	12 pathfinders 168 B-29's	0145 to 0329	97	72	14,800—16,000	5/10 to 10/10	11 158	M47A2 M17A1	68.8 1524.5 1593.3	1992 6098	50 50

tween fire companies. All in all, the stage had been set to wage a well organized fight.

a. The first planes arrived a little after 0130 hours and the first bombs fell in line with the 35° axis of attack, short and to the right of the aiming point. Later bombs fell on the south half and northeast quarter of the city. Fires quickly sprang up where the bombs fell. Many of the fire trucks started to pump water out of the system. Within the first 15 minutes, a cluster of bombs hit the electric switch station knocking out all electric power. The public water pumps failed, so that the only supply for the underground system was the 2,700,000-gallon, gravity-feed reservoir. Water pressure dropped to five pounds per square inch. The reservoir was drained in 1½ hours. About an hour after the first fires, nearly all the fire equipment was concentrated along the east-west main street, attempting to keep the fires from crossing. A stand here might have been successful except for two factors, (1) the public water systems failed entirely and (2) bombs were falling in the northeast quarter. Trucks were then dispatched to the northeast section and a new line was formed at the center north-south street. The northwest section was still without fire as no bombs had fallen there. As the last of the water in the underground system was used, most of the fire equipment was withdrawn across the bridges to the north side of the river, but some 15 fire trucks were able to drive onto the sand beach on the south bank and draw water. The river was so low that no more trucks could get to the narrow beach pools. Relaying of the water was not attempted. A number of the trucks caught fire, hose was burned, and one truck had its motor knocked out by a direct hit by an M50 bomb. A few of the trucks that had been stationed on the south edge of the city stayed there to protect public buildings, but none assisted in fighting dwelling fires, as they dared not move their equipment away from the buildings to which they had been assigned. Thus, the fire raged, spreading across all the main streets and consuming 0.95 square mile of the city proper. No assistance was sent to the suburban areas.

b. One of the most unusual features was the rupturing of cast-iron water pipes by direct hits of M50 incendiary bombs after they had penetrated four feet of soft earth in unpaved streets. This contributed to the early failure of the public water supply.

c. During the attack the wind continued to blow from the southwest. It increased in intensity during the attacks to 25 miles per hour but held the same direction. Only a few people reported a high wind of "fire storm" intensity. Nobody reported rain during the fire.

VII. Fire Damage and Casualties

1. *Buildings destroyed:*

	Number
Hachioji	14,327
20 locations in eight suburbs	1,007
Total	15,334

Important damaged buildings are listed below and are located on Figure 1 by number.

Building number	*Name of important buildings burned*
1.	Railway management office.
2.	Mitsubishi Bank.
3.	Yasuda Bank.
4.	Post Office.
5.	Private trolley company station.
6.	Seven grammar schools.
7.	Garage bus line station.
8.	Hachioji Technical School.
9.	Shno Jukogya Co. (silk plant with 200 employees).
10.	Small loading plant for primers.
11.	Government railroad station.
12.	Hospital at Tawasogo (100 beds).
13.	Local tax office.
14.	Local government (city hall) Tokyo Prefecture.
15.	Local government (town hall).
16.	Tama Girls Technical High School.
17.	Military police office.
18.	National Mobile Labor office.
19.	Two juvenile reformatories.
22.	Kew bus stall.
23.	Military preparatory school (at Yokoyama).
24.	Nihon Tokushu Noyaku (insecticide manufacturing).
25.	Electric transformer station.
26.	Health Insurance office.
	Imperial Forestry Department.
	Courthouse.
	Town Hall of Asakawa and its fire station.
	Telephone exchange at Yokoyama.
	Three local news agencies.
	Hospital at Mijita (70 beds).
	Hospital at Nagmacho (40 beds).
	Hospital for railway employees (40 beds).
	Four theaters.
	Two mercantile association buildings.

2. *Casualties and fire department losses:*

Public:	
Killed	305
Seriously injured	192
Slightly injured	599
Fire department:	
Firemen killed	6
Firemen injured	29

3. *Fire-fighting equipment:*

Fire stations destroyed	4
500-gpm pumpers destroyed	13
250-gpm pumpers destroyed	5

4. *Cause of fire damage.* The fire chief of Hachioji gave the following reasons in order of importance why the fire could not have been held in check:

a. City too densely built up.

b. All buildings were combustible.

c. Lack of water in the street system and lack of prepared locations at the water's edge.

d. Lack of adequate direction to the firemen and of coordination between the Tokyo and Hachioji fire equipment.

e. Lack of man-made or other adequate fire breaks.

f. Failure of civilians to stay and fight fires as bombs fell.

VIII. Analysis of Data

1. *Comparison of Japanese and Twentieth AF data:*

Subject	*Twentieth AF data*	*Japanese data*
Total number planes in vicinity over Hachioji	169	150.
Total number planes over the city		100–150.
Altitude	14,800 to 16,000 ft.	15,000 feet.
Time	0145–0329 local time	0130–0330.
Visibility	5/10 to 10/10 clouds	Cloudy.
Type bombs	Magnesium and oil	Magnesium and oil.
Tons of M47 bombs on Hachioji	68.8	50.
Tons of M17 clusters on Hachioji	1582.3	1,000.
Area of damage in Hachioji	1.2 square miles	0.95 square mile.
Area of damage in suburb	0	0.2 square mile
Estimated ground wind	Light SW	5-10 mph SW.

2. *Japanese bomb data on malfunctions (estimate):*

a. Five percent of the M47s were duds.

b. Twenty percent of the M50 bombs were duds. (Most of these were found in paved streets.)

c. Five percent of the M17 clusters failed to open. (An appraisal of this estimate is made in paragraph 11, herewith.)

3. *Japanese comments on the attack and ensuing fire:*

a. The attack was too long. It would have been more effective if compressed to 1 hour. (Note, however, that continuing the attack after the first hour did cause further damage in the northwest section.)

b. The attack was far too heavy—too many bombs fell on areas already afire.

c. The fire reached conflagration stage only after the water failed, then advanced north to the river. This area was already partly ignited by bombs.

d. The area of "fire spread" (area in which no bombs fell) composed 25 percent of the total burned area.

e. The fire department believed that it could have controlled the fire, at least in the northwest section, if water had been available in the street system.

f. A "fire storm" of short duration developed. (Only a few persons noted it, and its occurrence is questioned.)

g. The wind increased from 5-10 to 25 miles per hour at the peak of the fire. The light natural wind was never completely offset by the fire wind.

h. A night attack is more destructive than a day attack because of the encumbrances of darkness.

i. High explosives would not have deterred the firemen nor increased the damage commensurate with their weight.

j. The antipersonnel feature of the incendiary bomb was effective in discouraging prompt handling of the bombs.

4. *Extinguishment of the fire.* An attempt was made to determine what stopped the fires. By observation and interrogation, practically every point along the fire fringe could be checked with reference to one of two causes.

These were: (1) professional or civilian fire fighting; and (2) open spaces of varying distances. It was found that most of the professional fire fighting had been done in the north half of the city near a river bridge, and that most of the civilian fire fighting had been done on the south side where the wind blew the smoke and heat away from the fire fighters. The combined effect of civilian fire fighting and natural wind is illustrated on Figure 1 by the irregular fire perimeter and the twenty isolated fires on the windward (south) side; whereas the fire perimeter on the leeward side is much more regular, except at one location where professional fire fighting was effective, and there were no isolated fires. Although it was not possible to check every incident, the professional and civilian fire fighting probably did not stop fire spread along more than 20 percent of the perimeter. Thus, open space was the greatest contributing factor in stopping the fires from spreading.

a. The relative effect of open spaces of varying widths on fire spread (exposure distances) was determined by estimating the distance up to 55 feet between the burned and the nearest unburned building to the nearest five feet, and to the nearest 10 feet from 55 to 100 feet, around the entire perimeter. Small isolated fires outside the main body of fire were excluded from this study. So few cases of exposure between 100 and 200 feet occurred that all distances beyond 100 feet were classified as "No Exposure." It was possible to make a fairly equal separation of the exposure distance figures into those on the windward and the leeward sides, respectively, by considering the main east-west street as a natural dividing line. Figure 1 shows the exposure distances as they were determined around the fire fringe ("no" means no exposure); Table 2 gives the various totals of the segments of the perimeter within increments of 10 feet on both the windward and leeward sides.

b. If it is assumed that streets of the same width occurred in equal number on each side of the main east-west street; that the effect of fire fighting was approximately equal on each side; and that fires stopped at a certain exposure distance only after they had had an opportunity of stopping at a lesser distance, then a good check can be made (1) on the direction of the fire spread; (2) the effect of a 5-10-mile-per-hour wind in causing fire spread; and (3) the effect of distance in preventing fire spread against a light breeze. In Table 2, columns 2 and 6 give the actual distance of each increment exposed. Columns 3 and 7 give their relative percentage to the total perimeter for each side. Columns 4 and 8 give the accumulated percentage for the exposure distance, or the probability of non-fire spread. Columns 5 and 9 give the probability of fire spread at each of the increment distances. Figure 3 shows these same results graphically. Here it is readily seen that: (1) the direction of fire spread was predominantly to the leeward; (2) the amount of fire spread averaged about 20 percent more on the leeward than on the windward side; and (3) the probability of fire spread varied with the distance and direction of the wind. For example, at Hachioji, the probability of fire spread across a 50-foot open space to a combustible building was found to be 67 percent

TABLE 2

[See Figure 3 for plotted graph of these figures]

	Windward side				Leeward side			
Exposure distance in feet (1)	Perimeter distance in feet (2)	Percent of total windward perimeter (3)	Accumulated percent of total windward perimeter (4)	Percent probability of fire spread (5)	Perimeter distance in feet (6)	Percent of total windward perimeter (7)	Accumulated percent of total windward perimeter (8)	Percent probability of fire spread (9)
5–15	1,430	6.7	6.7	93.3	0	0	0	100.0
16–25	3,080	14.3	21.0	79.0	940	6.5	6.5	93.5
26–35	3,350	15.6	36.6	63.4	1,810	12.5	19.0	81.0
36–45	1,380	6.4	43.0	57.0	940	6.5	25.5	74.5
46–55	2,200	10.3	53.3	46.7	825	5.7	31.2	68.8
56–75	275	1.3	54.6	45.4	1,320	9.1	40.3	59.7
76–100	1,155	5.4	60.0	40.0	1,870	13.0	55.3	44.7
100 plus	8,570	40.0	100.0	0.0	8,100	56.0	100.0	.0

with, and 48 percent against, a light breeze.

c. Typical examples of fire fighting on the windward side, where the direction of the wind must have been of assistance, are shown in the photographs following. Photo 1 shows the remains of a burned building 10 feet from an unburned combustible building, where use of water buckets by two men prevented fire spread. Photo 2 shows a corrugated-iron, wood-frame shed 15 feet from a burned factory. Buckets of water were used by neighbors. Photo 3 shows a combustible dwelling with the remains of a burned factory 20 feet distant in the foreground and a burned dwelling 10 feet away at the rear. A boy and his father saved their house with buckets of water dashed on the side of the building to cool it off. Photo 4 shows a combustible dwelling 20 feet from a burned factory. The side boards and fence took fire but were extinguished by a man and his wife. Photo 5 shows the scorched schoolhouse that would have burned had it not been for the fire apparatus stationed here for its sole protection. The foundation of a burned school building remains in the foreground. Photo 6 shows two rolling, steel fire doors that saved the adjoining structure. Active fire fighting by the fire department is evident on the unburned portion. Photo 7 shows a concrete, wing-type, parapeted fire wall between two combustible structures. The fire department was active here also. Photo 8 shows the remains of a burned building adjoining a fire-resistive structure. The wire-glass windows and a steel fire door (door not shown) prevented fire entering the fire-resistive building. People inside watched but did not fight the fire.

5. *Incendiary bomb penetration*

a. Penetration in concrete roofs. Hachioji was not a good city to check the penetrating properties of the fire bombs, for there were only a few reinforced-concrete buildings in the city and not one was hit by M47 bombs. Four concrete roofs were hit by M50 bombs. One school building (260 by 40 feet) with a nine-inch concrete roof received five bomb hits. The eight-inch concrete roof of the Telephone Exchange building (125 by 40 feet) received 21 hits. The eight-inch concrete roof of the Hachioji Credit Association building (25 by 40 feet) received six hits, and the Mitsubishi Bank building (25 by 40 feet) six-inch concrete roof received two hits. No bombs perforated any of the roofs. The depths of penetration are recorded in Table 3.

TABLE 3

	School building	Telephone exchange	Hachioji association	Mitsubishi bank
Number M50 bomb hits	5	21	6	2.
Thickness roof	9 inches	8 inches	8 inches	6 inches.
Penetration depth	1 bomb 4 inches.	1 bomb 5 inches.	1 bomb 4 inches.	2 bombs 1 inch.
	2 bombs 3 inches.	4 bombs 3 inches.	3 bombs 3 inches.	----------
	1 bomb 1 inch.	2 bombs 2 inches.	1 bomb 2 inches.	----------
	1 bomb ½ inch.	6 bombs 1 inch.	1 bomb 0 inch.	----------
	----------	8 bombs ½ inch.	----------	----------

Photo 9 shows some of the 21 hits and photo 10 shows the deepest penetration of five inches on the telephone exchange building.

b. Penetration in combustible roofs. An attempt was made to determine the degree of penetration by the M50 in roofs of combustible buildings. The results proved statistically unreliable, so only impressions are given here as gathered from the Japanese people:

(1) In general, the M50 bomb had excessive penetration, often burying itself in the ground after perforating the roof, ceiling, tatami mat, and ½-inch wood floor. In this position the bomb burned, sometimes either setting fire to combustible trash or the underside of the floor—a most difficult place to extinguish a fire.

(2) In 2-story structures, the bomb seldom perforated to the earth through two floors, the ceiling and the roof. It usually landed on its side on the tatami mat of the first floor, having been diverted from a straight fall by the mat above. These bombs were the most effective in starting fires.

(3) Nonperpendicular falling M50s often crashed through the roofs and ceiling but failed to ignite. (All-ways fuzes would have made these bombs function.)

c. Perforation of water mains. Unusual perforation was exhibited when the M50s penetrated four feet of soft soil and pierced cast-iron pipe or broke the pipe. The city water works engineer found one 16-inch-diameter, cast-iron pipe pierced through both sides, another eight-inch-diameter pipe pierced through

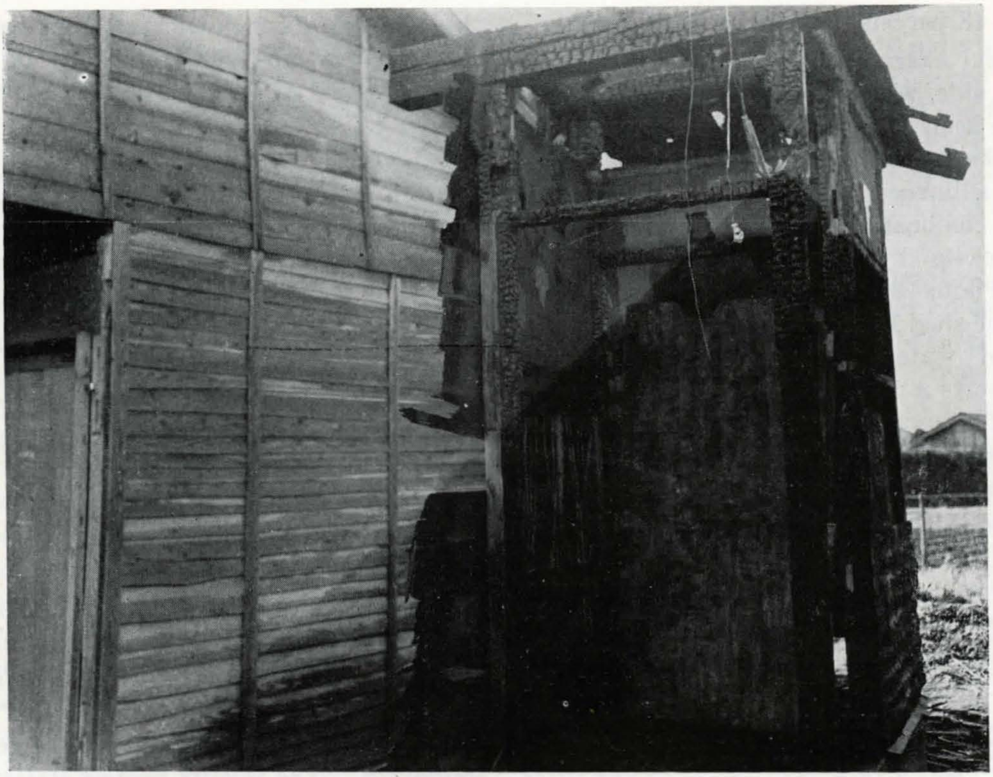


Photo 1.—Remains of a burned building exposing an unburned building 10 feet away. Water buckets were the only fire equipment used.

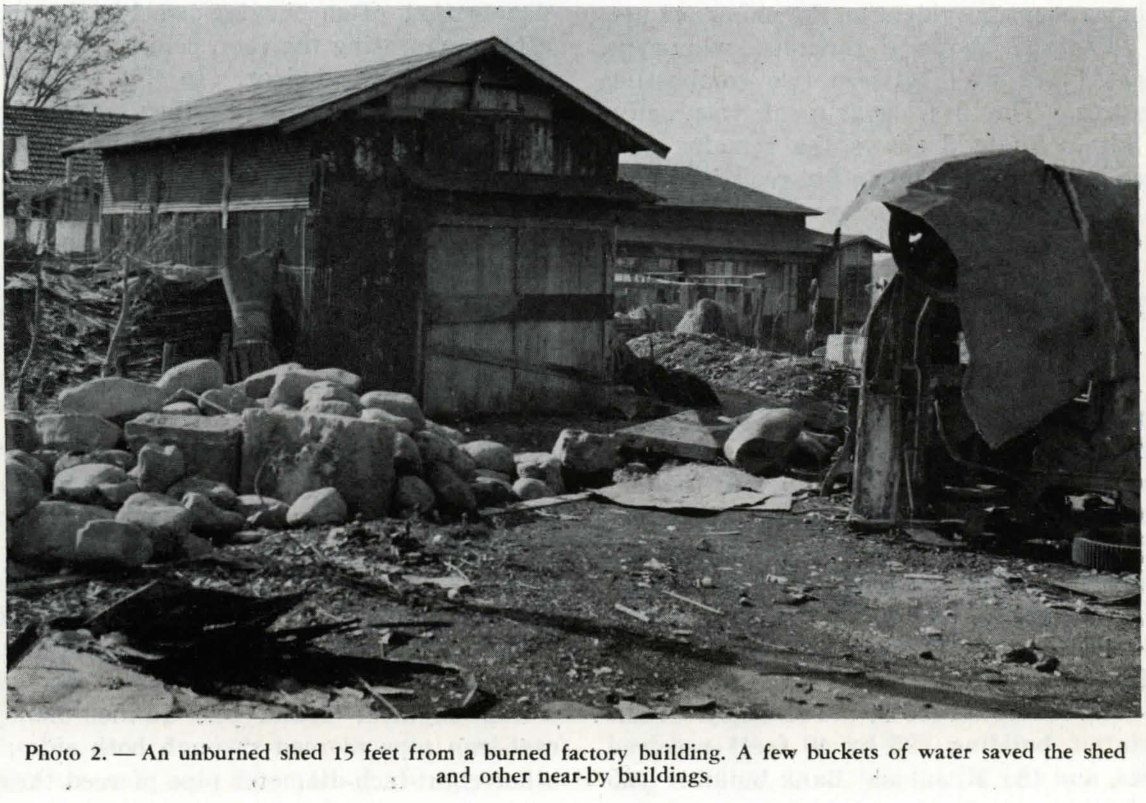


Photo 2. — An unburned shed 15 feet from a burned factory building. A few buckets of water saved the shed and other near-by buildings.

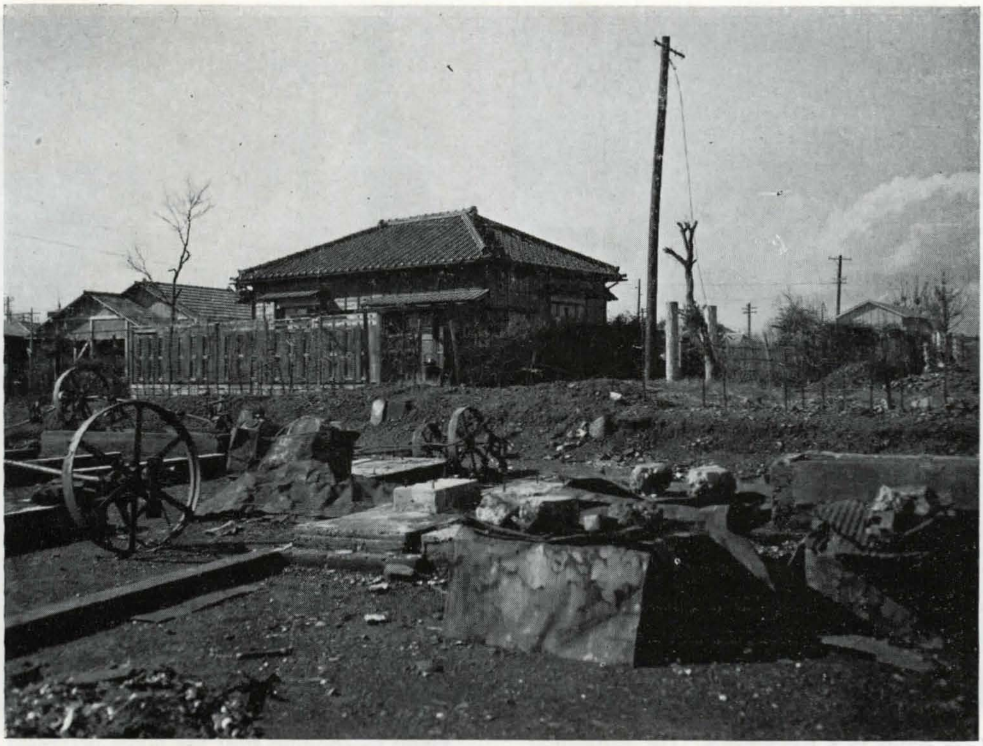


Photo 3.—An unburned dwelling 10 feet from a burned factory and 20 feet from burned dwellings. Water buckets were used to fight the fire.

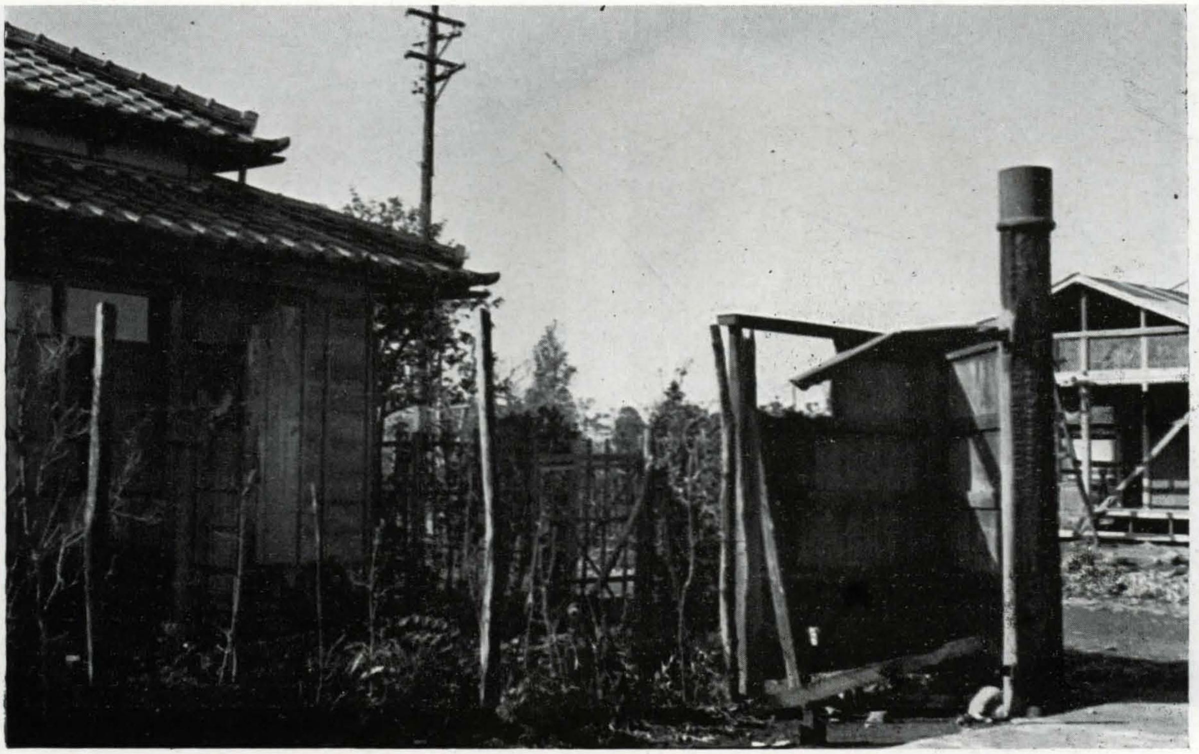


Photo 4.—A hand pump was used to extinguish a fire which started on the dwelling 20 feet from a burned factory.

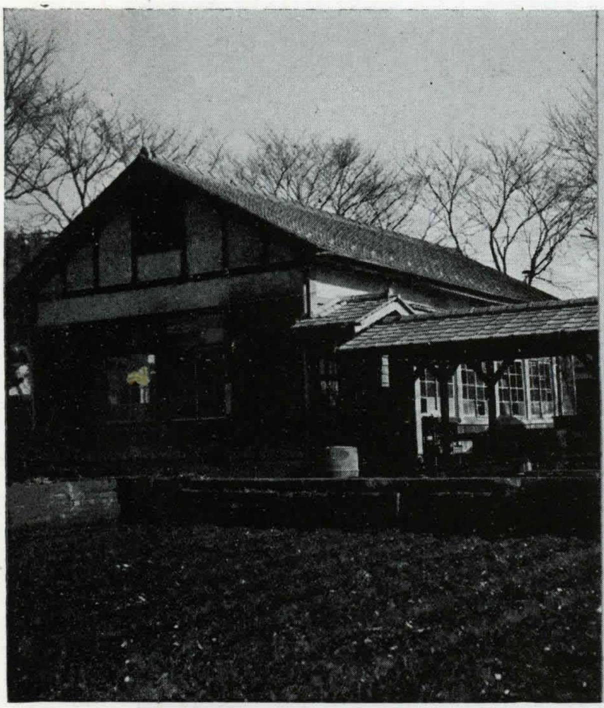


Photo 5.—Burned siding of a schoolhouse. The foundation of the burned building is in the foreground.

Photo 6.—Rolling steel fire doors prevented fire spread to the adjoining building.

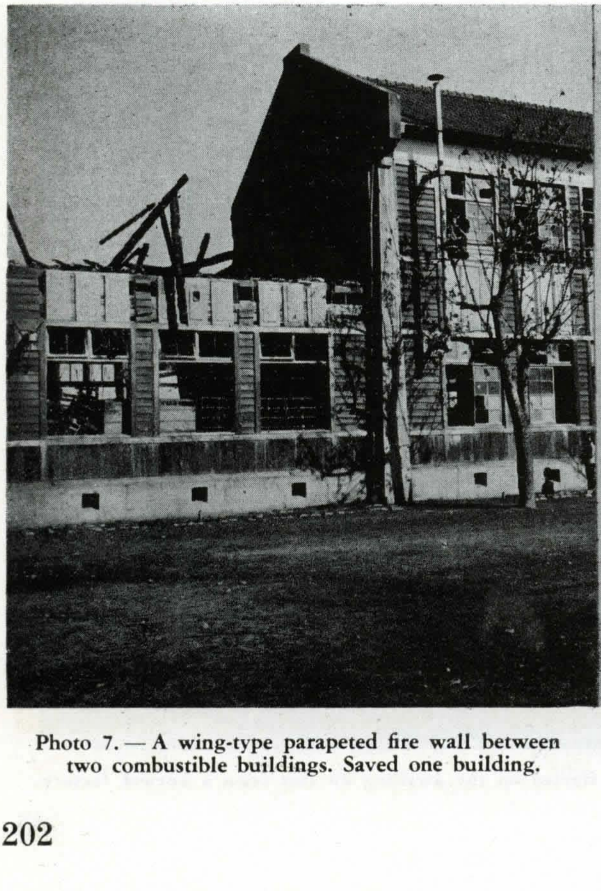


Photo 7. — A wing-type parapeted fire wall between two combustible buildings. Saved one building.

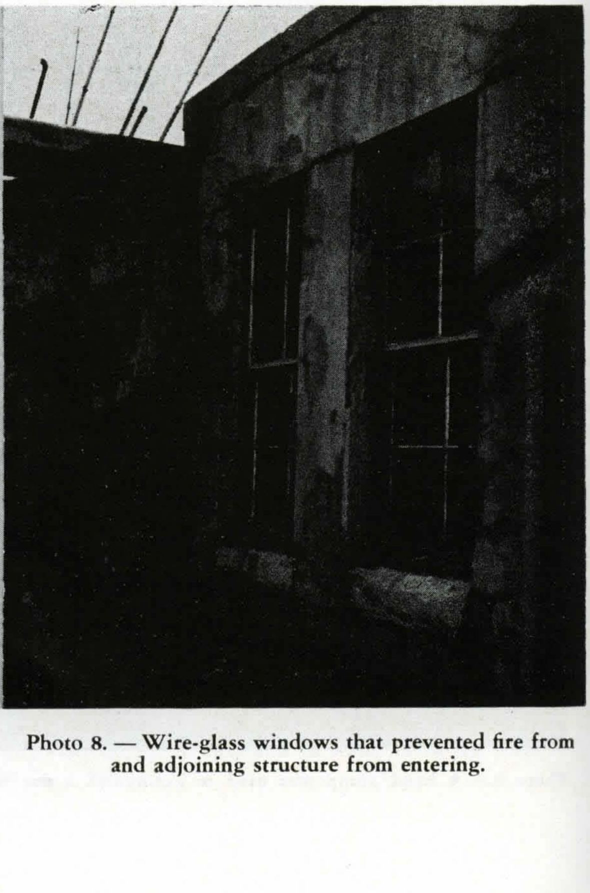


Photo 8. — Wire-glass windows that prevented fire from and adjoining structure from entering.

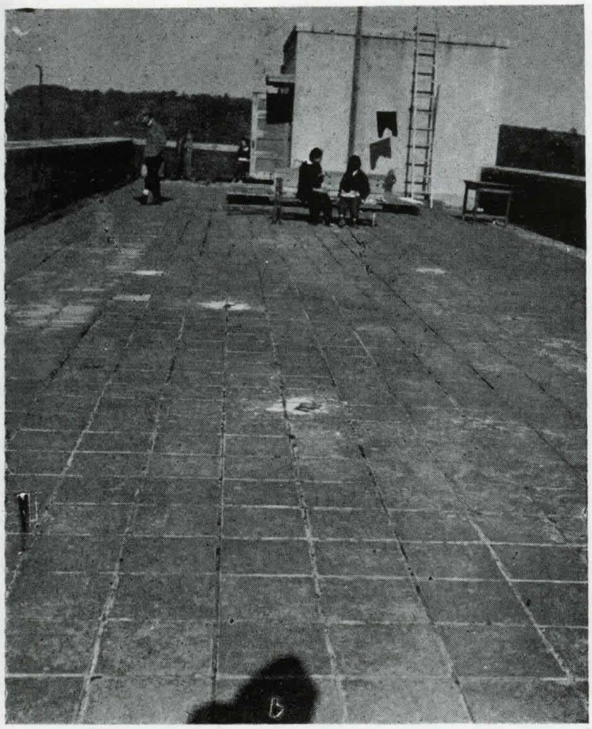


Photo 9.—Marks of the M50 bomb on the heavy concrete roof of the Telephone Exchange Building.

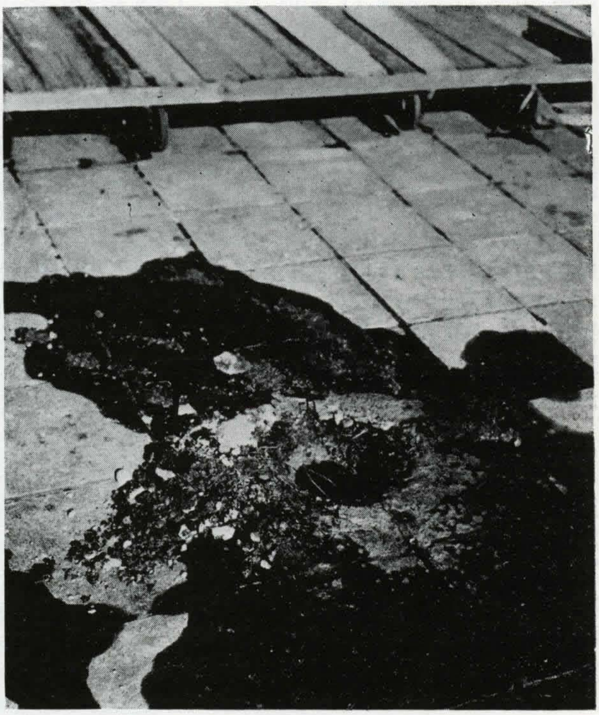


Photo 10. — The 5-inch penetration made by one M50 bomb in the concrete roof.

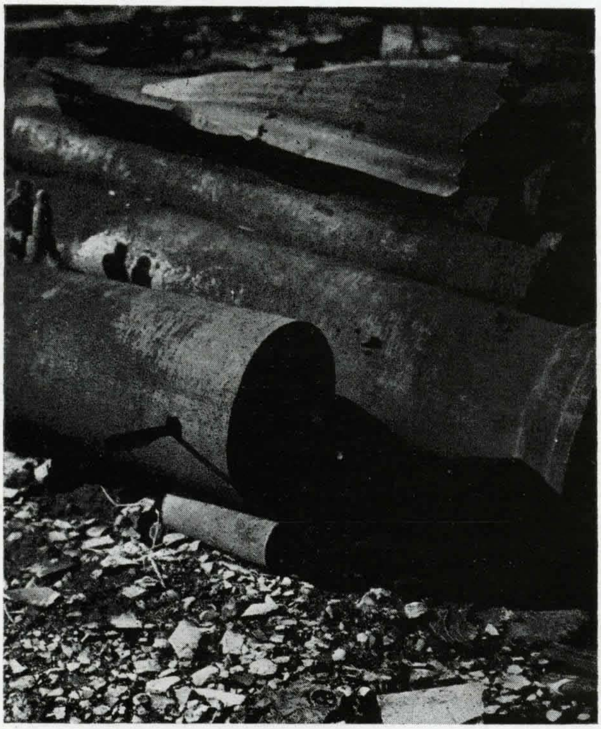


Photo 11. — Shows a 16-in.-diameter cast-iron water pipe pierced thorugh both sides by an M50 incendiary bomb.

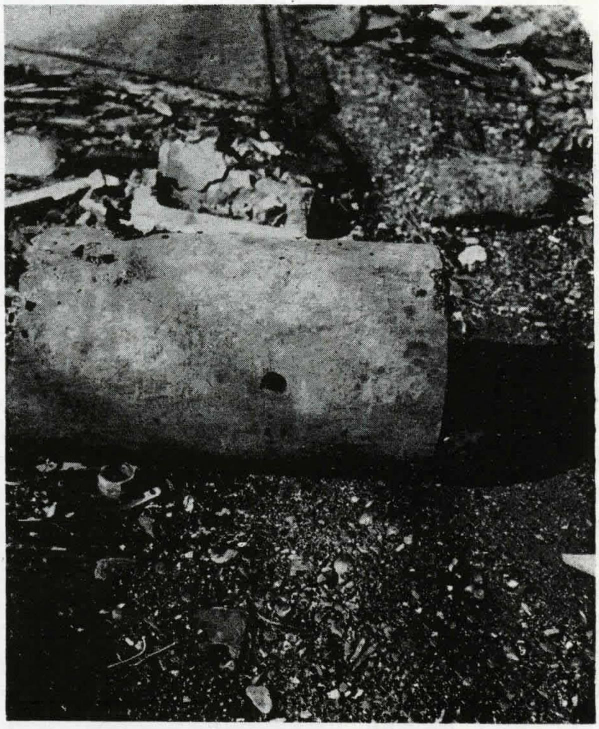


Photo 12. — Shows a 16-in.-diameter cast-iron water pipe pierced through one side by an M50 incendiary bomb.

one side (Photos 11 and 12). One eight-inch one six-inch, and 13 four-inch-diameter cast-iron pipes were also broken by M50 bombs in unpaved street.

d. Perforation of "godown" roofs. The bombs perforated the mud roofs of "godowns." These roofs were usually tile on mud fill on ½-inch wood sheathing over 8 to 12 inches of mud plaster and bamboo laths. Photo 13 shows an unburned "godown" and photo 14 shows one burned with the roof caved in. It was definitely established that a single M50 bomb perforated the roof and ignited the contents.

6. *Ignition by fire bombs*

a. Ignition by M47 bombs. The M47 (70-pound oil) bombs arrived first and started a few fires along the south side of the city. There is little doubt that they started fires rapidly with a direct hit and often set fire to as many as three dwellings. As Hachioji was predominantly highly built up, the M47 had an average chance of 30 percent (average of 30 percent roof area) of starting a single fire by a direct hit, or 70 percent (open space) chance of starting up to three fires by gel from near-misses splattering on sides of buildings. The large amount of fire equipment and the waiting men held the early fires in check. The quickly started fires may have been of some advantage to the visual-bombing planes which arrived later.

b. Ignition by M50 bombs. The use of the M50 bombs came as a big surprise to the people. Many of them had fought fires in Tokyo and were familiar with oil bombs, but had considered the M50 obsolete. Their statement was that the bombs fell with considerable force and many exploded while burning. (Ten to 20 percent had explosive noses.) The bomb was easy to handle during the first three minutes, but was most difficult to get at when it penetrated beneath the dwelling. Bombs that fell outside the dwelling in the soft earth shot up burning pieces of magnesium to a height of 10 feet. Moist soil especially made the bombs appear like Roman candles. Often these chunks of fire ignited combustible material near by. There is little doubt that these bombs started fires with considerable frequency in places where they were difficult to extinguish. The large amount of combustible material under, around and in Japanese houses made this bomb a much more effective fire raiser than had been anticipated from previous tests on a bare structure.

7. *Efficiency of the attack.* Figure 2 shows the location of all the burned suburban areas. Twenty such locations are listed and they indicate rather wide distribution of the bomb fall. Several of these suburbs were spot checked for bomb density. One case showed evidence of a single plane load, whereas three others showed evidence of more than a single plane load stick. An oval ring that encloses 19 of the 20 suburban incidents and which is estimated as the probable limit within which 95 percent of the bombs fell has been drawn on Figure 2. It is possible that the shape of the oval area should be more nearly circular, but the hills beyond the flat sides of the oval contained no buildings and thus furnished no evidence. This oval has axes of 37,500 and 19,000 feet which are nearly the proportions of the damaged city itself (10,000 by 5,000 feet). Single-plane bombing with short bomb sticks usually produces a normal distribution about the mean point of impact. If it is assumed that a normal Gaussian distribution was obtained—there is good evidence of this by the uniform distribution of isolated burned areas about the main burned area—then about 22 percent of the total reported bomb load dropped, fell on the city. This gives an average density of approximately 200 tons per square mile. On the other hand, if the Twentieth AF estimated that 50 percent of the bomb fall within a radius of 4,000 to 5,000 feet was obtained by radar bombing with good identification, an average density of 445 to 285 tons per square mile fell on the city. Still a third estimate can be made from the 34 bomb hits on the 17,000 square feet of roof area of the four concrete buildings located in the center of the city (described under "Penetration" in section VIII–5). This indicates a bomb density of 123 tons per square mile. Since these 3 estimates appear to be in reasonably good agreement, it is estimated that an average density of 200 to 300 tons fell on the city, burning out .95 square mile, and the remaining weight fell on a 21-square-mile area, burning out 0.2 square mile of property.

8. *Fire spread.* An attempt was made to

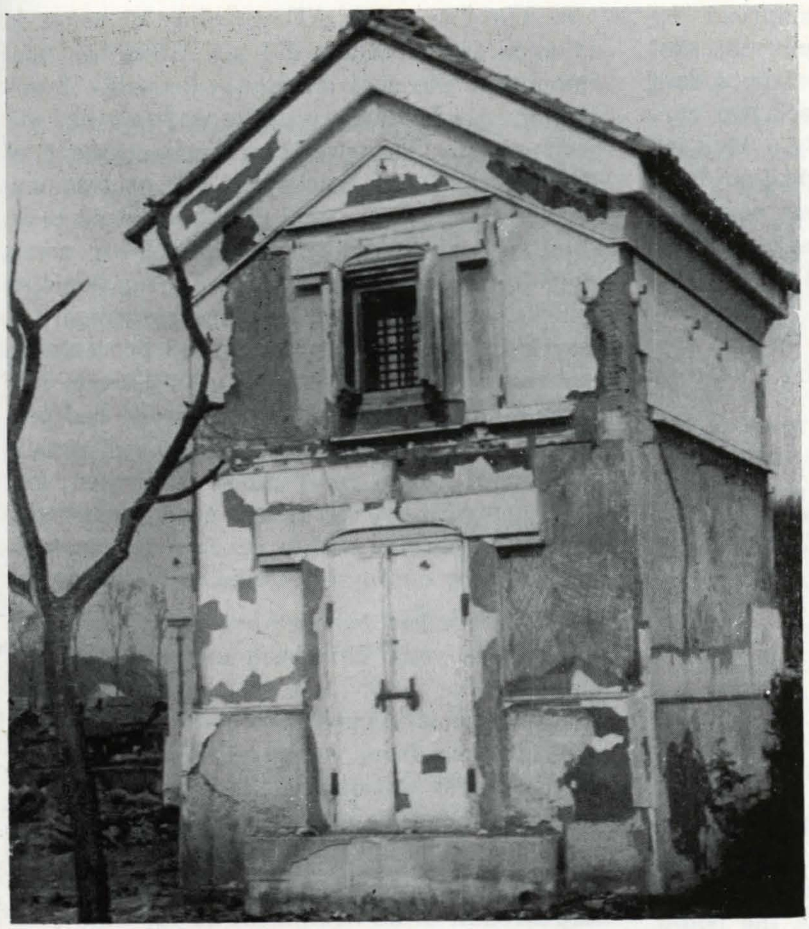


Photo 13.—A Japanese "Godown" constructed of heavy mud plaster on bamboo lath walls. The roof was tile on mud plaster on wood boards. Heavy metal doors afforded protection against fire and theft. This "Godown," or treasure vault, survived an intense fire. Note how the heat denuded the tree, spalled the outside plaster coating and cracked the wall.

Photo 14.—The interior of a burned Japanese "Godown" showing the collapsed roof. Note the thick roof and wall indentations where the wood studs were used.

determine the total amount of "fire spread" by checking the number of burned city blocks, distinguishing between those hit by bombs and those that escaped. A detailed check was carried out in the east end of the city. This involved so much time that a straight-line sampling was made the length of four south-to-north streets. If a single impression of the bomb body was found in a block of the asphalt road, that block was considered as having had bomb-initiated fires. The results of the detailed check and the four samples are shown in Table 4.

TABLE 4

	Blocks without bombs	Blocks with bombs	Total street blocks	Spread factor (blocks without bombs over blocks with bombs)
				Percentage
East end	9	22	31	41
1st strip	4	19	23	21
2d strip	4	17	21	23.6
3d strip	3	20	23	15
4th strip	4	25	29	16
All blocks	[1] 24	103	99	23

[1] Four of these blocks were on the windward side.

The table shows fairly even distribution of bombs over the two-mile city length. Any error would be in favor of a lower spread factor, since it was most difficult to locate the bomb body impressions. Confirming the above 23 percent spread factor obtained, Hachioji officials estimated that about 25 percent of the blocks burned without being hit by bombs; and 20 percent fire spread was found on the leeward side alone.

9. *Accuracy of the attack*

a. Based on the shape of the burned area, and the assumed limits of bomb fall, the mean point of impact has been measured as being only 715 feet west of the aiming point.

b. The axis of attack was briefed at 35°. It was reported at 19° to 62° in the mission report. Interrogation indicates that the planes came from the general direction as briefed, but many came in outside the 19° to 62° sector. The bombing of the water reservoir, the electric transformer station and the main east bridge early in the attack was good evidence of the wide-spread distance from the aiming point.

10. *Appraisal of the pre-attack warning on the extent of damage.*

a. The Twentieth AF warning 30 hours in advance of the attack did not affect the final amount of physical damage. Probably fewer people were killed than if the warning had not been given. The prefectural government of Tokyo sent 50 fire trucks and 300 professional firemen to assist the local fire department in an all-out effort to determine whether or not a large force could control fires resulting from air attacks. Two items of chance determined the results in favor of the attack and prevented a real test: (1) the choice of the M50 bomb with its excellent penetration, which broke and perforated buried water pipes in unpaved streets and caused loss of reservoir-stored water; and (2) a lucky hit put the electric transformer station out of service within the first fifteen minutes, thereby ending all public water pumping.

b. If there had been no breaks in the water pipes, there would have been an adequate water supply in the reservoir for 180 125-gallon-per-minute hose streams for 2 hours, plus a few hose streams from the river supply. If the electric power station had not been hit, (it was 0.64 mile from the aiming point) there would have been 48 additional hose streams for an indefinite period. In view of the potential 290 hose streams of all equipment at one time (180 from the reservoir, 48 from the water pumps, and 62 from the river), there is some reason to believe that the fire damage would have been considerably less if the water supply had escaped damage.

11. *Appraisal of malfunctioning fire bombs.* The Japanese gave an estimate of five percent M17 clusters and M47 failures, and 20 percent M50 bomb failures, but they were unable to locate or produce a single cluster, so it is doubted that an accurate check was made. The five percent M47 failures is normal, but, to have obtained this percentage of unfired bombs, the actual failures would have had to be higher, since an unfired M47 will burst from internal pressure when in a burning area. Likewise, 20 percent failures of the M50 bomb is high but may be accounted for by the fact that the estimate was obtained from bombs picked up in paved streets where mechanical injury and malfunctions are most common. In general, the estimates of duds indicate the order of magnitude rather than accurate figures.

IX. Conclusions

1. *Vulnerability.*

a. Hachioji was highly built up, and, in general, inadequately prepared for an air attack.

b. The Japanese dwelling was highly vulnerable to fire; even a poor incendiary bomb could be effective in starting fires in Japanese buildings.

c. Little use was made of noncombustible building material to retard the spread of fire.

d. This attack provided the only case in attacks on Japanese cities where a high ratio of firemen and equipment stood ready for the attack. In spite of this preparation, the weight of the bombs and loss of the water supply overwhelmed the defense.

2. *Conflagrations.*

a. More than 25 percent built-upness with combustible structures is a prime requisite for conflagrations.

b. Preliminary organization of fire reserves is highly desirable.

c. The failure of water supply is one of the most critical items to guard against in fighting a conflagration.

d. Many small controllable fires do not make a conflagration. It is only when the fires become uncontrollable that the conflagration starts.

e. A fire wind of 25 miles per hour experienced during the fire did not greatly affect the direction of the natural wind.

3. The psychological warfare tactics of warning the enemy in advance did not alter the final extent of fire damage. It might have seriously lessened the results except for a fortunate choice of bombs and a lucky hit.

4. The Japanese estimated percentage of 20 percent M50, five percent M17 clusters and five percent M47 "duds" was unreliable.

5. The choice of the M50 bomb, the time, altitude and aiming point were well planned. The tonnage of bombs dispatched was more than double that usually considered necessary by the Air Force for a target of this size. It was probably double that required to obtain the same amount of damage.

6. *Accuracy of the attack.*

a. The estimated mean point of impact was 715 feet from the aiming point.

b. An estimated 50 percent of the load or 800 tons of bombs fell well within the 5,000-foot radius of the aiming point.

c. There was a wide difference in the briefed axis of attack, the executed direction, and the range reported in Mission Report 306.

d. An estimated average density of 200 to 300 tons per square mile fell on the central burned portion of the city.

7. Spread (i.e., fire beyond the area of bomb fall) accounted for the fires in one-fourth of the blocks in the city; four-fifths of these were on the leeward side, one-fifth on the windward. The chance of fire spread across an open space varied from about 70 percent at 25 feet to 40 percent at 75 feet on the windward side, compared to 90 percent and 50 percent for the same distances on the leeward side.

8. *M50 bomb penetration.*

a. Heavy concrete roofs (six inches or thicker) prevented perforation.

b. In general, the M50 has too much penetration for Japanese domestic structures; however, a few of the bombs that did perforate the floors started fires that were the most difficult to extinguish.

c. The heavy mud "dozo" roofs of "godowns" were pierced by M50 bombs.

d. The high penetration of the M50 made an unusual contribution to the success of the attack by breaking buried water mains in unpaved streets.

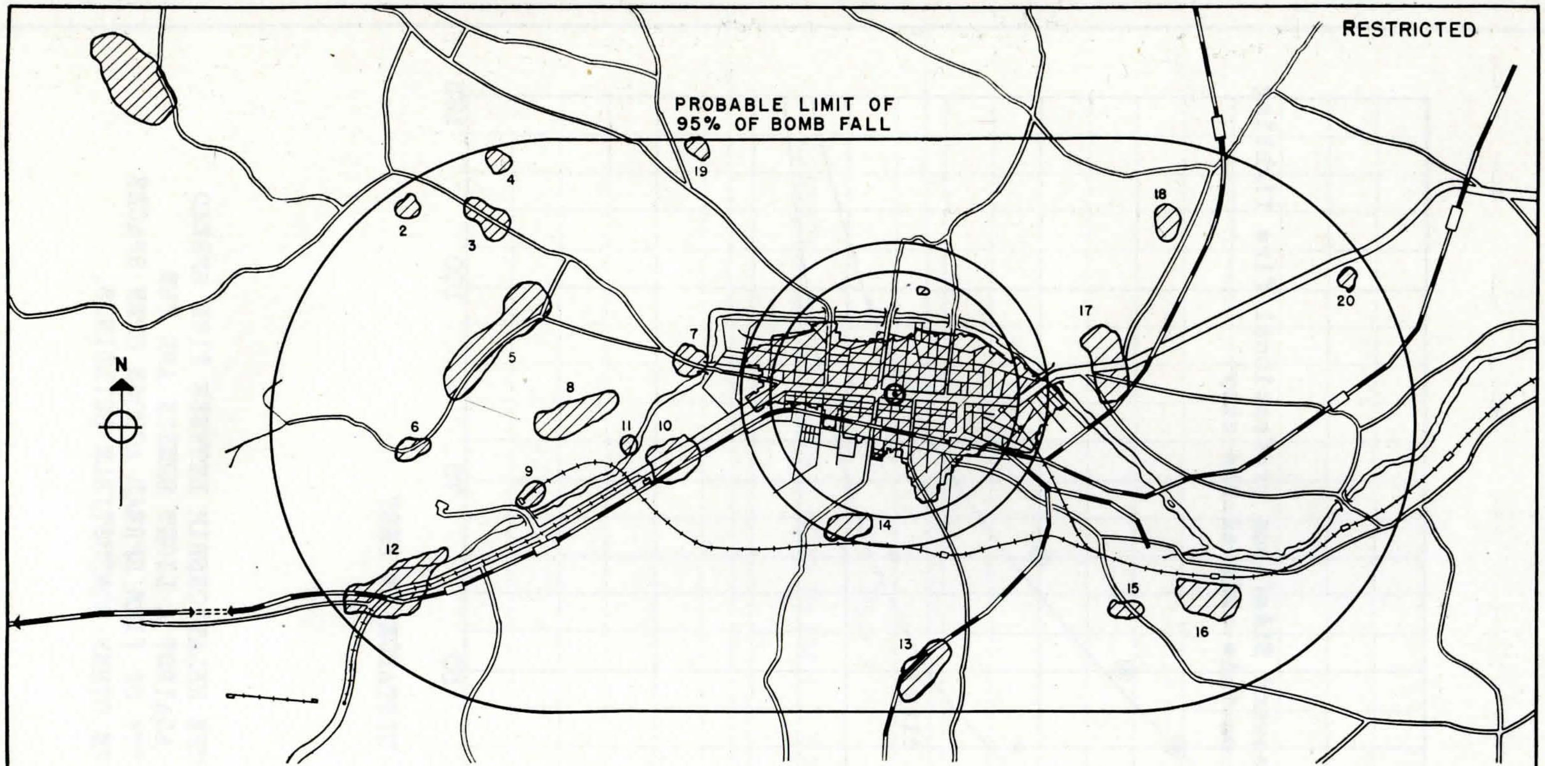
9. The M50 was not an especially good fire raiser, and was fairly easy to handle. It was successful because of the antipersonnel feature, the close spacing and the combined effectiveness of large numbers.

X. Appendices

1. Figure 1. City map of Hachioji showing burned area, location of main water pipes, aiming point, planned and limit of CPE, main buildings, and distance between burned and unburned buildings around the perimeter.

2. Figure 2. City map of Hachioji and location of damage in suburbs with the probable limit of 95 percent bomb fall indicated.

3. Figure 3. A graph of Table 2 showing the relationship between the probability of fire spread and exposure distance.



LEGEND

1. YAMAIRI, KAWAGUCHI - MURA
2. NIBUGATA, MOTO HACHIOJI - MURA
3. SHIMO - ICHIBUGATA, HACHIOJI - MURA
4. KAMI - ICHIBUGATA, HACHIOJI - MURA
5. MOTO - HACHIOJI, NO. 1 SECTION, HACHIOJI - MURA
6. MOTO - HACHIOJI, NO. 2 SECTION, HACHIOJI - MURA
7. YOKOKAWA, HACHIOJI - MURA
8. FUNEDA, YOKOYAMA - MURA
9. SHIMO - NAGABUSA, YOKOYAMA - MURA
10. SANDA, YOKOYAMA - MURA
11. MILITARY PREPARATORY SCHOOL, YOKOYAMA - MURA
12. KAMI - KUNUGIDA, ASAKAWA
13. KATAKURA, YUI - MURA
14. TAMA - JUVENILE REFORMATORY, YUI - MURA
15. UCHIKOSHI, YUI - MURA
16. KITANO, YUI - MURA
17. OWADA - MACHI, HACHIOJI CITY
18. ISHIKAWA - MACHI, HACHIOJI CITY
19. INUME, KAWAGUCHI - MURA
20. HINO, HINO - MACHI

▨ FIRE DAMAGED AREA

DAMAGED
SUBURBS
OF
HACHIOJI
JAPAN

SCALE

1000 0 1000 2000 FT.

RESTRICTED

U.S. STRATEGIC BOMBING SURVEY
HACHIOJI, FIRE
HACHIOJI, JAPAN
FIGURE 2

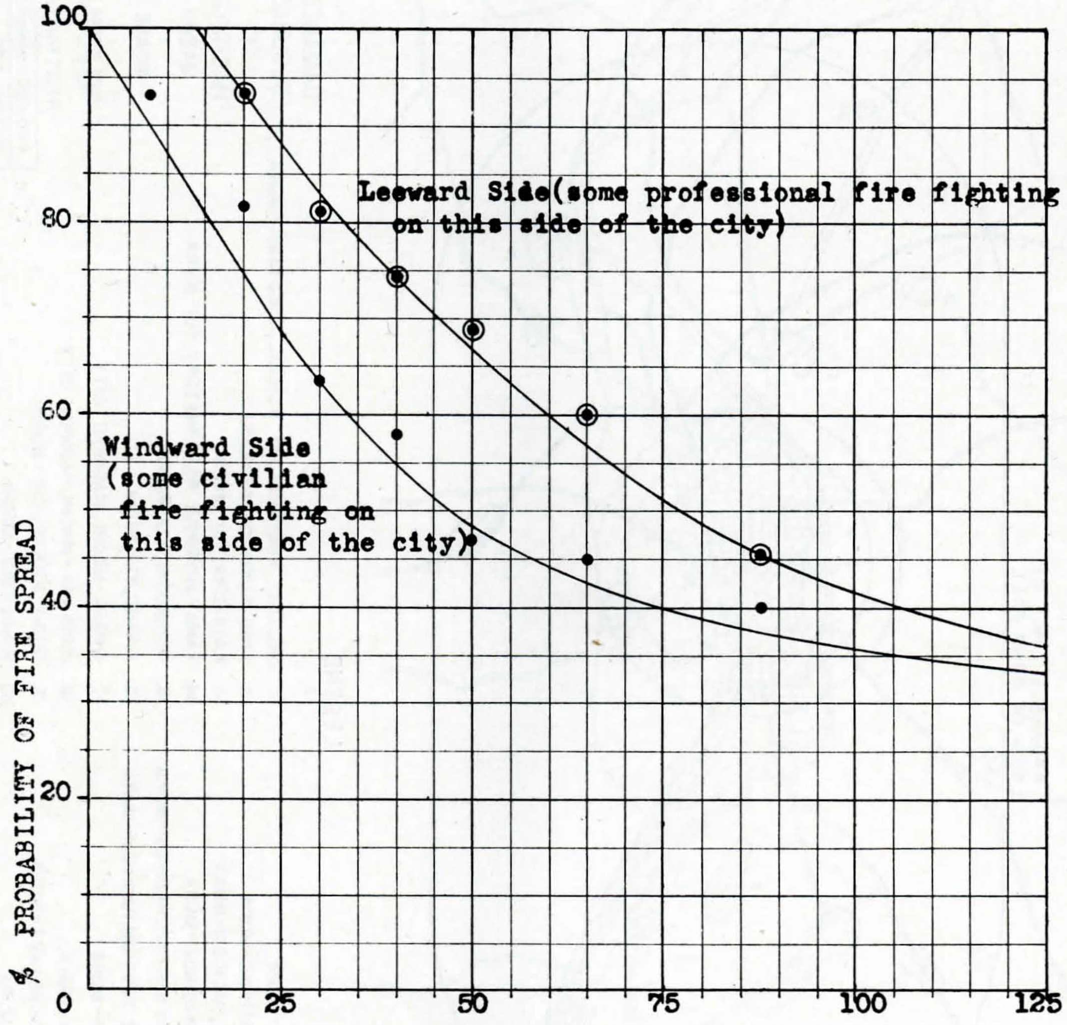


Figure 3- SHOWING THE RELATIONSHIP BETWEEN FIRE SPREAD WITH AND AGAINST A LIGHT BREEZE AND THE PROBABILITY OF FIRE SPREAD ACROSS OPEN SPACES TO INVOLVE OTHER COMBUSTIBLE BUILDINGS.

Part 7

EFFECTS OF INCENDIARY BOMB ATTACK ON UBE, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 213

II. SUMMARY 213

III. GENERAL INFORMATION 213

IV. THE TARGET 214

V. THE ATTACK 215

VI. FIRE DEFENSE DATA 215

VII. ANALYSIS OF DATA 216

VIII. PHOTOGRAPHIC INTERPRETATION EVALUATION 218

IX. RECOMMENDATIONS AND CONCLUSIONS 219

X. APPENDICES 220

    Figure 1

    Night Photos 1 and 2

    Mosaic

I. Object of Study

1. The primary objective of this study was to uncover pertinent facts regarding the effectiveness of the M47 and M69 fire bombs dropped on the city of Ube, Japan, on 2 July 1945. This city was of special interest to the Army Air Forces and the United States Strategic Bombing Survey, in that it showed less damage per ton of fire bombs than the average of the 66 Japanese cities attacked. As all operational conditions of the attack were normal, and the types of fire bombs were those most commonly used, the facts herein presented can be of value in comparison with those accumulated in studies of other Japanese cities.

2. The secondary objective was to evaluate the accuracy of the Central Interpretation Unit, XXI Bomber Command, Damage Assessment Report 118, prepared from strike and post-strike photographs.

II. Summary

1. A fire and weapons study was conducted on Ube, Japan, to determine the extent of fire damage, the effectiveness of incendiary weapons used, and the accuracy of photo interpretation. Ube is located on the Inland Sea at the southwest tip of Honshu Island near Shimonoseki. The city was relatively small, had a population of 100,000, and occupied approximately two square miles of built-up area. Its long narrow shape, curving along the ocean front, made it more difficult to hit than an ordinary target.

2. A total of 714 tons of M47 and M69 bombs was dropped from the 100 B–29 planes at 10,000 to 11,000 feet on the night of 1–2 July 1945. It is estimated that some 500 tons of incendiary bombs fell in the target area, of which 150 tons landed in the center of the city and burned 0.49 square mile. Other attacks on the city were high-explosive attacks, and thus presented no problem of separating damage.

3. The center of the city was badly damaged; 5,000 dwellings, more than a hundred commercial buildings, and another hundred light-manufacturing buildings burned. Casualties were 230 killed or missing and 456 treatment cases. Not a single reinforced-concrete or noncombustible structure was involved in the fire area. Although only one-half square mile burned, it represented half of the most inflammable target area. Large industrial buildings were located mainly on the fringe of the urban area and suffered only slight damage.

4. Fire defense was weak. The fire department had not been augmented during the war, nor had special training been given to civilians. People fled the city during the attack, leaving a small fire department and some 1,000 persons to fight the fire. In spite of this weak defense, conflagration conditions were not reached. The "Spread Factor" was estimated at 20 percent.

5. An attempt was made to establish the density of bombs on the city center. It is believed that 100 to 200 tons landed on the burned-out part, averaging 300 tons per square mile. The accuracy of the attack was likewise assessed. The Centers of Impact were 1,500 and 3,500 feet from the two aiming points.

6. Photo interpretation of the total damage underestimated the actual damage by 2.2 percent of the total area of the city. Photo intelligence was found to be reliable.

III. General Information

1. On 6 November 1945, Maj. F. J. Sanborn, fire and weapons engineer, Lt. H. C. Montgomery, Jr., USNR, photo interpreter, and Lt. John Holtom, USNR, language interpreter, working as members of Physical Damage Division Field Team No. 1, interrogated public officials and manufacturers in gathering information to explain the rather low fire damage resulting from the 2 July 1945 attack. The study consisted of interviews and an inspection of the physical damage, plus an analysis of aerial photographs.

2. No attempt was made to verify, by a detailed study of the records or damaged buildings, the information obtained. The Japanese city officials seemed sincere and willing to cooperate, and there appeared to be no reason to suspect that the information given was not as accurate as would be obtained by further checking.

3. A fire-damage map of the city was furnished by the fire chief. A check of its accuracy showed that the fire-fringe line was correct for each block, but that it did not attempt to show the exact outline for each building within the

block. The map is, therefore, suitable for measuring the total area of damage but not suitable for making an exposure-distance fringe study (i.e., the distance of the burned from the unburned buildings).

4. It should likewise be noted that estimates of items such as planes, altitude, number of bombs, time and percentage of duds are all in round figures, whereas the numbers of dead, casualties, homes destroyed, personnel and fire equipment are given in exact figures indicating their degree of reliability. It is the opinion of the Survey Team that the figures given are reasonably accurate.

IV. The Target

1. The city of Ube was located on the coast near the southwestern tip of Honshu, 25 miles east of the narrow Shimonoseki Straits between Honshu and Kyushu. It had a population of 100,000 and an over-all area of 15 square miles. The greater part of the densely populated area was compressed along the waterfront with an east-west axis of two miles and a north-south axis of one-half mile. The Mashime river divided the town into two nearly equal sections.

2. Although the city was old, the dwellings had kept pace with the times, changing gradually in design with the years. The majority of the homes were flimsy one- and two-story structures, similar to those found elsewhere in Japan. Some of the factory-owned homes near the industrial plants were of the row type, but only a few of these and no modern concrete structures were involved in the fire. The predominant occupations (i.e., mining and fishing) did not influence the type of home. Likewise the arrangement of buildings was similar to that in other Japanese cities: houses faced the streets and had little or no space between them. Backyard gardens, little alleys, heavy overhanging eaves, shops, dwellings, and shrines were all a part of the city.

3. Ube was industrially important for submarine coal mines, synthetic oil plants, the largest magnesium plant in Japan, the third largest nitrogen fixation plant, and other chemical plants, but, as practically none of these was involved in the 2 July 1945 attack, they are not covered specifically in this report.

4. The military importance of the city was established by its industrial importance. As all of the large industrial plants were located along the water front, bordering only on the fringe of the residential area, it was unlikely that the industrial plants would be involved by exposure fires which would result from an incendiary bomb attack on the city. Therefore, the most that could be gained was the dehousing of workmen and destruction of the commercial-residential area together with its small workshops. This goal was achieved by the attack.

5. The burned commercial-residential area comprised the central and oldest part of the city. The new concrete city hall and municipal buildings were not involved. In fact, not a single reinforced-concrete structure was affected in the entire attack. The dwellings, without basements, having wooden foundations 1½ feet above the ground, ½-inch wood floors covered with rice straw mats (tatami), ¼-inch wood ceilings, tile on wood (mud fill) roofs, and mud plaster on bamboo lath walls were typical of those on Honshu. Two-story structures had open stairways; inner partition walls had either thin plaster or wood sliding doors. Homes were known in size by the number of three- by six-foot mats which could be placed in the sleeping room. Families averaged five members and dwellings averaged approximately 500 square feet of floor area.

6. The Japanese-prepared damage count showed one commercial and one industrial building for each 50 dwellings. Manufacturing shops in homes were fairly common. Often the front of the house was used for making small wooden items (e.g., baskets, tubs, shoes); for repairing bicycles; for tailoring; or for the sale of household articles.

7. Charcoal braziers provided heat for cooking and home heating. Central heating systems were found only in large commercial or industrial buildings.

8. Public utilities and services were generally good. Electricity was common, gas was available, underground water mains were well distributed, there were a few telephones, and the streets were well paved. These utilities are not covered further in this report as they were not materially affected.

9. The total built-up portion of the city included 1.8 square miles of which 1.1 square

miles were considered adequately covered for incendiary attack. In the 1.8 square miles of built-up area, the following density existed:

10 percent was 0- 5 percent built-up.
14 percent was 5-20 percent built-up.
54 percent was 20-40 percent built-up.
22 percent was 40-50 percent built-up.

Thus it can be seen that Ube was as densely built-up as other Japanese cities of comparable size but, considering the elongated shape and the high built-upness along the water's edge, it was probably a less remunerative incendiary target.

V. The Attack

1. This city had not been attacked prior to 2 July 1945. The high-explosive bombs dropped later did not fall in the fire-damaged area and therefore presented no problem of identification.

2. The Twentieth AF records show that Mission 242, 2 July 1945, dispatched to Ube 112 B29 planes from Wing 313, carrying only incendiary bombs. Seventy-one planes bombed visually, 29 by radar through 0/10 to 5/10 clouds, at 0147 to 0312 hours from an altitude of 10,000 to 11,600 feet. The bombs dropped were 183.6 tons of M47A2 and 531 tons of E46 clusters fused to open at 5,000 feet (38 M69s to a cluster). The E46 clusters were dropped at 50-foot intervals, the M47s at 100-foot intervals. There were two aiming points in line with the axis of attack (325°). The enemy defense was weak and inaccurate, and no planes were lost. (Table 1.)

VI. Fire Defense Data

1. *Equipment and personnel.* The Ube fire chief stated that he had had 36 professional and 16 auxiliary firemen at the "big fire" with six pieces of motorized fire equipment and adequate fire hose. Three additional fire trucks arrived to assist at the end of the attack. The people were poorly trained and disciplined. Since the prefectural government had not expected an attack on the city, it had not established major firebreaks, prepared evacuation areas, supplemented its fire-fighting facilities, or made other preparations. Early in the war the people had been trained to extinguish the four-pound magnesium bomb but had not been trained in the best method of extinguishing oil bombs. The quota of professional fire equipment and personnel was the *same at the time of the attack as in peacetime.* Judged by United States standards of one man per thousand population the fire department was undermanned. Fires were only one-half as frequent, however.

2. *The "big fire."* The "big fire," as related by the Ube fire chief, started at 0130 hours and was under control at 0600. All six pieces of motorized fire equipment were used and all 36 professional and 16 auxiliary firemen fought the fire, assisted by three outside trucks and 15 firemen that arrived about 0330 hours from another city. The firemen fought the fires wherever they could. No strict line was formed except that the river served as a major line of defense. Two pieces of fire equipment were lost in the fire and all the motorized fire equipment failed (except two pieces made in America) before the fire was out. Approximately 1,000 persons assisted in fighting fires in their own homes. This low number was due to the fact that the people were tired of the war, were dissatisfied with food and living conditions, and, judging from the experience of other cities, felt that they could not save the city. Lack of training and of organization was apparent. The people fled to the hills carrying their belongings, blocking the roads, and even leaving some patients to burn in the hospitals. The electricity failed early, and a few lead gas pipes melted, thereby adding to the general

TABLE 1.—BOMB ATTACK DATA

Mission No.	Date	Air Force	Wing	Target location	Primary or Secondary	Planes dispatched	Planes over target	Visual Bombing	Radar Bombing	Time (local)	Altitude of attack	Bombs tons (clusters)	Intervalometer spacing	Visibility	Aiming points
242	2 July 1945.	20th AF.	313	Ube	Primary	112 B-29s.	100 B-29s.	71	29	0147-0312.	*Feet* 10,000-11,600.	183.6 M47. 531 E46.	*Feet* 100 50	0/10 5/10	108104. 125067.

confusion. The Ube fire chief stated that he did not have the authority to assign the people to fire tasks and the Ube police chief said that, although he had the authority to keep people in the city and assign them to tasks, there was no fire equipment for them to use.

3. *Water supply.* The water supply was adequate and no shortage developed during the fire. The system was gravity feed from a reservoir, with direct pumping from the river to the mains in case the demand exceeded the capacity of the reservoir. This emergncy condition was not reached.

4. *Climatic conditions.* At the time of the attack, there had been no rain for several days, and a five-miles-per-hour wind was blowing from the southwest. A wind of 25 miles per hour developed at the peak of the fire and rain fell for an hour on the leeward side of the fire. This was the usual "fire storm" phenomenon, caused by condensation of water moisture and soot from burning gas.

5. *Progress of fire.* In spite of the lack of men, equipment, and training, and the presence of favorable weather, *conflagration conditions were never attained.* Instead, individual buildings and blocks burned out without much spread of fire. Street widths, low built-upness on the leeward side, lack of high winds, the elongated shape of the city, and lack of concentrated bombing were major factors in preventing attainment of the conflagration stage. Firebreaks would have been of little use. Credit must be given to the small fire department that did much to arrest the fires after the bombers left.

VII. Analysis of Data

1. *Comparison of Japanese and Twentieth AF Data:*

Subject	*Twentieth AF data*	*Japanese data*
Total No. of planes in Ube area.	100	70.
No. of planes over city center.	100	50.
Altitude	10,000–11,600	6,000–8,000.
Start of attack[1]	0147 (mission report).	0130.
End of attack	0312	0400.
Visibility	$^{0}/_{10}$–$^{5}/_{10}$	Clear.
Type bombs	M47 and M69	100- and 6-lb. oil.
Tons M47 over city.	183.6	227 (estimate).
Tons M69	531	350 (estimate).
Area of damage in city.	0.42 square mile.	0.49 square mile.
Ground wind	5 mph SW	5 mph SW.

2. *Japanese data on bomb malfunctions.*

a. Ten percent of the M69s were duds (only 5 percent at Ube Nitrogen Fertilizer Co.).

b. 5-10 percent of the M47s were duds.

c. In general the M47s arrived first in the attack and started fires in at least one and often as many as three dwellings at once. The M69s were good fire raisers, being adequate to start a fire if left unattended.

3. *Japanese losses by fire.*

a. Casualties:

165 persons killed.
456 cases required treatment.
65 persons missing.

b. Buildings damaged:

4,952 houses destroyed.
106 commercial establishments destroyed.
107 manufacturing buildings destroyed.
341 buildings partly damaged.

c. Other damage (beyond repair):

2 pieces of fire equipment.
50 automobiles.
100 telephone poles and street lighting equipment.

d. Industrial damage.

The industrial damage was reported as follows:

(1) *Ube Steam Power Co.* The coal conveyor was hit and burned, causing the plant to be inoperative for a week.

(2) *Higashimisome colliery.* This station sustained 459,365 square feet of plan area damage by fire to its factory-owned dwellings, sheds and outside equipment, causing a loss in production of 43,000 gram tons (of 2,268 pounds each).

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[1] Photos taken at 0140 show city well alight with bombs and fire.

(3) *Ube Nitrogen Fertilizer Co.* Fire damaged the conveyor, fertilizer storage, paraffin producing plant, oil, and straw bag storage buildings. Plant officials estimated the production loss would have been 50 percent, had it not been for the fact that the plant was running only at 10 percent capacity at the time because of a coal shortage. (400 M69s and 40 M47s were found on the premises, 22 M69s were duds.)

4. *Japanese opinions of the attack*

a. The raid was of too long duration without compression of the attack. Many fires could be attacked as individual fires before spreading to other buildings.

b. The fires never reached conflagration stages because of the low wind, natural arrangements of the wide streets, fire-fighting activities, and elongated shape of the city.

c. The fire spread involved only 10 percent more area than the area in which the bombs fell.

d. The fire department believed it could have controlled the fires to one-half the damage, if the civilians had remained in the city. Likewise, the loss could have been further reduced if additional fire equipment had been available for civilians and the fire department.

e. The rain of the "fire storm" that developed one hour after the attack did not reduce the fire damage.

f. The direction of the wind was pronounced throughout the fire, blowing from the densely to the sparsely populated area. (This undoubtedly accounts for the small amount of fire spread.)

g. A night attack was more effective than a day attack would have been because of the encumbrances of darkness.

h. High-explosive bombs would not have added greatly to the damage, unless underground services had been damaged. (All aboveground buildings were destroyed in the fire area.)

i. Reinforced-concrete buildings within the burned area would not have assisted in stopping the spread of fire, or have given shelter to the fire department, unless located on the windward side.

5. *Survey estimates and compilations.*

a. The night photographs taken shortly after the start of the attack show that the bombs were dropped over a two-square-mile area. The fact that only 20 percent of the property fronting the ocean was damaged indicated that great care was exercised to keep the bombs over land. The Japanese estimate of the number of planes, and the corresponding excellent estimate of the plane loads indicate that approximately 70 plane loads were dropped over the two square miles of the city. Thus the following estimates are given:

(1) Maximum number planes over target area	100
(2) Minimum number planes over target area	50
(3) Probable number planes over target area	70
(4) Probable number tons on target area	500
(5) Average tons per square mile	250
(6) Probable tons in the 0.42-square-mile burned area	150

b. Two aiming points were assigned for offset bombing—both being in line with the axis of attack (shown as points "A" and "B" on Figure 1). The wind was blowing from the southwest as determined by interrogation and night photographs, thus keeping both points free of smoke at all times. The earliest night photographs show fires burning some 3,000 feet from aiming point "A". Photographs taken 9 minutes later show fires burning within 1,000 feet of aiming point "B". Still later photographs show fires burning fiercely from the river to 5,000 feet southeast of point "B". Several buildings are identified as shown on the transparencies and ground map. Photos taken 1 hour later show the same points still burning plus other near-by buildings. The accuracy of the attack is listed as follows:

	Aiming point "A"	Aiming point "B"
	Feet	*Feet*
Nearest main fire to aiming point	2,000	400
Nearest individual fire to aiming point	900	100
Nearest industrial fire to aiming point	900	350
Center of impact to aiming point	3,500	1,500
	Feet	
Distance between aiming points	8,000	
Burned distance between aiming points	6,000	

c. The effect of built-upness is shown by comparing the various built-up portions within the burned area. Thus it is seen from the following that 82 percent of the burned portion was more than 30 percent built up.

Percent built-upness in burned area	*Percent of burned area*
0–20	4
20–30	16
30–40	26
40–50	56

d. The 10 percent "Spread Factor" (the burned area without bombs over the burned area with bombs) estimated by the Ube fire chief appears low and was probably influenced by his fire-fighting position on the windward side. Considering that the fire burned to the sparsely built-up area on the leeward side, the fire spread must have been at least 20 to 30 percent on that side. Again, judging from the less well defined lines on the two sides parallel to the wind, the fire spread must have been at least equal to that on the windward side. An overall estimate of 20 percent fire spread is offered as a more probable figure.

e. The statement that *conflagration conditions were never attained* was based on the small amount of fire spread on three sides. Strangely enough, however, a "fire storm" of short duration occurred about one hour after the start of the attack, indicating intensive fires. The estimated density of 250 tons per square mile obtained is the only reason that can account for the apparent contradiction of non-fire spread and non-conflagration versus the completeness of the burned area.

VIII. Photographic Interpretation Evaluation

1. *Comparison of Statistics of Damage*

TABLE 2

	Actual		Reported	
	Area square mile	Percent area [1]	Area square mile	Percent area
Area of city	1.8		1.8	
Portion of city destroyed	0.46	25.5	0.42	23
Area of built-up urban zone	1.09		1.09	
Portion of urban zone destroyed	0.42	38.5	0.39	35.7
Area of built-up industrial zone	0.71		0.71	
Portion of industrial zone destroyed	0.04	5.6	0.03	4.2
Area destroyed outside of city	0.03		None	

[1] Percentage based on reported areas for comparison.

The above tabulation indicates a 2.2 percent error in under-reporting the *total* area of the city destroyed (0.04 square mile of unreported damage in the 1.8 square-mile city area.) This represents a 14.3 percent unreported error of damage based on the 0.49 square mile of actual damage. Considering the fact that the area had been a target of opportunity previously, when small scattered areas within the target had been destroyed, that the quality of photography was fair to poor, and that the report was prepared by a field unit, the small error seems easily explainable. In several cases the extent of damage was more accurately plotted from photography than by the Japanese fire department survey. An error of 0.01 square mile was made in reporting the destroyed portion of the industrial zone. While this area of damage is insignificant in relation to the area of the industrial portion of the target, the economic effects were of some importance. The 0.03 square mile of unreported destruction which fell outside the built-up urban and industrial areas was confined to isolated, closely built-up areas of institution or housing character. The 12 main locations missed by the interpreters are shown on the map, Figure 1, as Numbers 1 to 12. The general statements and statistical data included in this report give an accurate impression of both extent and distribution of damage resulting from the attack.

2. *Comparison of industrial damage.*

a. A later supplement to Report 102 (Twentieth AF Damage Assessment Report) gives a more detailed analysis of damage to industrial targets within the Ube area. Of 23 targets, no visible damage was reported on 16, minor damage was reported on four, and 50 to 100 percent damage on three.

b. The ground check indicated additional damage to industrial targets but not to a degree that would materially affect strategic planning. A comparative study of the 23 targets reported shows no damage to 13, minor damage to six, nine percent damage to one, and 80 to 100 percent damage to three.

c. The Ube Steam Power Plant No. 2, which sustained only minor damage, was totally incapacitated for one week because of the nature of damage. One incendiary bomb landed on a hard-to-replace conveyor belt. This damage could not have been detected from aerial photography; no visible damage was reported.

d. The Ube Nitrogen Fertilizer Co. was reported to have received no damage. Actually nine percent of the floor area was destroyed, including the entire paraffin plant and a straw bag plant for packaging the fertilizer. The company reports 90 percent production loss resulting from the nine percent physical damage.

e. The Ube Spinning and Weaving Co. was reported to have been 50 percent destroyed. Actually the damage was underestimated by approximately 30 percent and the company was totally incapacitated.

f. Other industries were found to be substantially as reported.

3. *Value of night photographs.* Night photographs (21BC5M242–156V7–2–0141 & 0147 & 0246) were taken during the attack. They are of special interest because of their importance in photographic damage interpretation and in the study of attack accuracy. The photographs were enlarged to the same scale as the Mosaic in Figure 2 so that direct overlay comparison can be made. The comparison shows the following:

a. If the night photographs had been used by the photographic damage interpreter, the Points of Damage 1, 3, 9, 10, 11, 12 listed on Figure 1 would not have been missed.

b. Night Photograph 1 is of particular value to a weapon effectiveness study because it shows the direction of wind and the clearly defined street pattern at Point 14. It also clearly defines the location of the river at Point 13, the **L**-shaped building at Point 3 and the burning buildings at Points 9 and 10. Since these photographs were taken at the start of the attack, they can be used to assess the accuracy of the pathfinder planes.

c. Night Photograph 2 clearly shows many bombs and brisk fires at Point 1 which were missed by the photographic damage interpreter. It shows also a cluster of bombs and fire going in the burned-out area of Point 15. Since fire fighting was active in this area, this additional group of bomb strikes provides the only logical answer as to why the fire burned south to the wide street, whereas adjoining areas were unburned on the south. Night Photograph 2 was taken one hour following Night Photograph 1 and indicates the extent of fire growth. At Point 10, only four buildings are shown burning in transparency whereas the later Night Photograph 2 shows six buildings afire. Likewise, the three well defined buildings at Point 16 later involved another building. Fires are less distinct in the last photograph indicating merging of fires or roofs that have collapsed.

IX. Recommendations and Conclusions

1. The selection of two aiming points, type and weight of incendiary bombs, time and altitude of attack were well chosen.

2. The execution of the attack was not so good in that the compressing of the attack into a maximum time of one hour was not achieved. Missing one aiming point by 2,000 feet reduced the anticipated level of damage.

3. The idea that industrial buildings would be seriously damaged by the urban attack was not well founded. No spread of fire to the large industrials resulted from the urban fires.

4. Conflagrations are a product of a rather complicated set of conditions, not all of which need to be present at the same time, but some of the more important must be in evidence. The order of relative importance, established by the survey team and the Ube fire chief, is as follows:

a. Wind exceeding 20 miles per hour.

b. Built-upness of more than 25 percent of combustible structures.

c. Combustible structures.

d. Compressed bombing.

e. Favorable weather prior to bombing.

f. Lack of professional fire fighting.

g. Lack of home fire fighters.

h. Lack of man-made firebreaks.

5. The supposed low return for this attack of 0.560 square mile per 1,000 tons of bombs was actually found to be 0.687 square mile per 1,000 tons. If the calculated probable density of 250 tons per square mile is used as a basis, then the

rate of efficiency was 4.0 square miles per 1,000 tons.

6. The actual amount of damage as interpreted from aerial photographs was underestimated by 14 percent of the city area. Industrial and other damage outside the city accounted for this. The photo intelligence interpretation was generally reliable. Night photographs could have been of value in locating other damaged areas and in assessing the accuracy of attack.

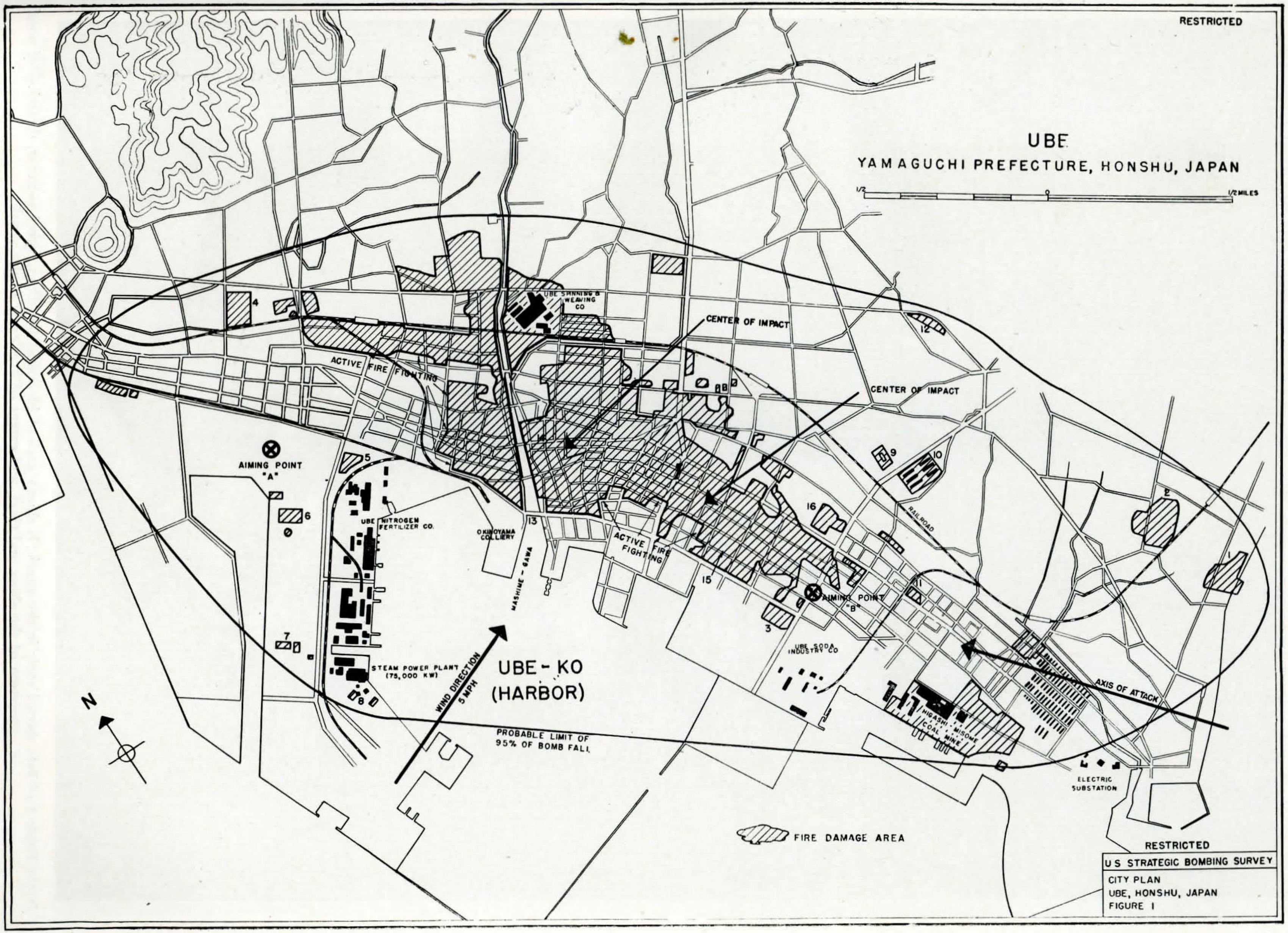
X. Appendices

1. Fire damage map of Ube (Figure 1).

2. Photo-mosaic of Ube following the attack (Figure 2).

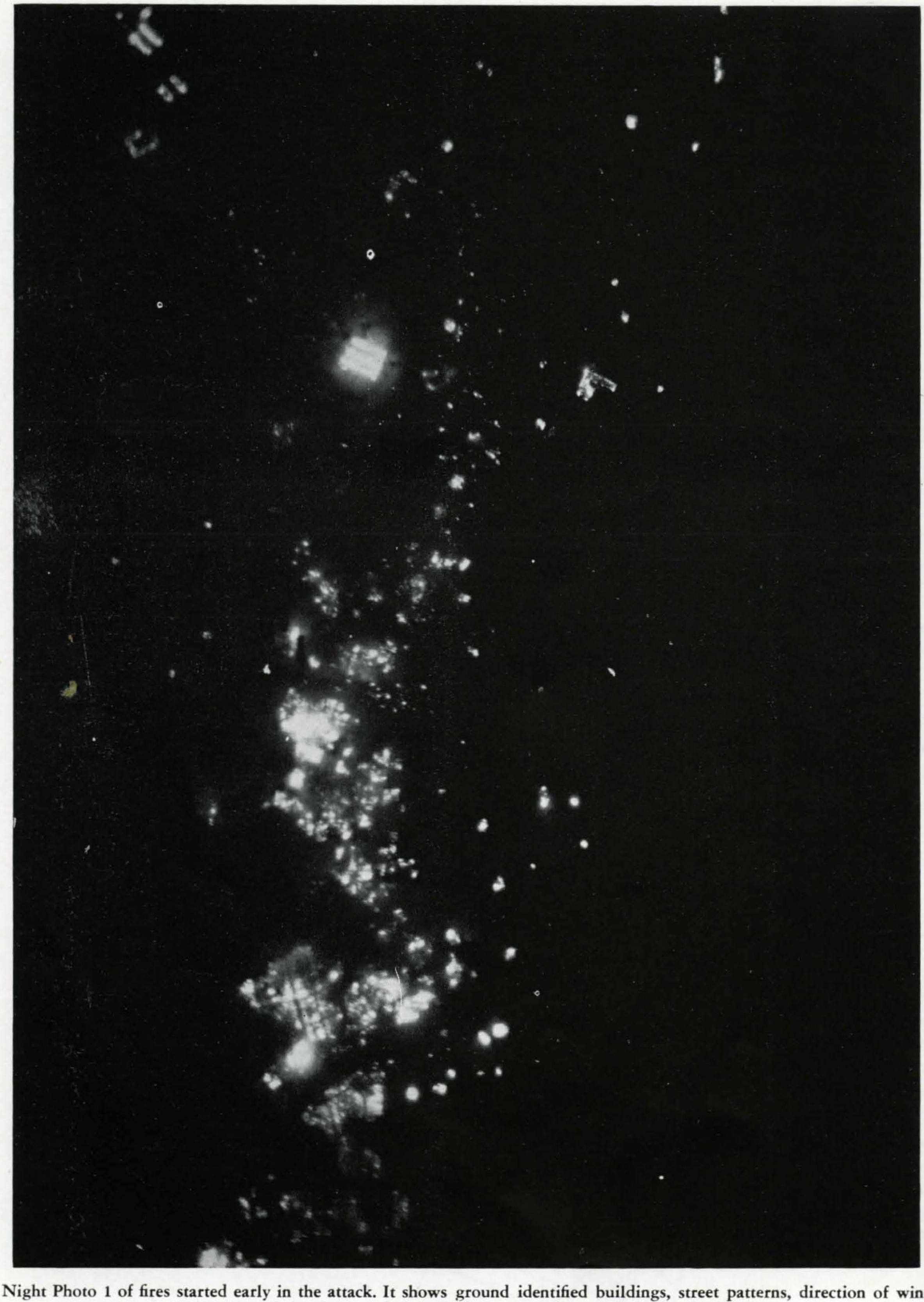
3. Night Photograph 1 taken during the attack showing identified buildings burning.

4. Night Photograph 2 taken 1 hour later showing results of some fire spread.

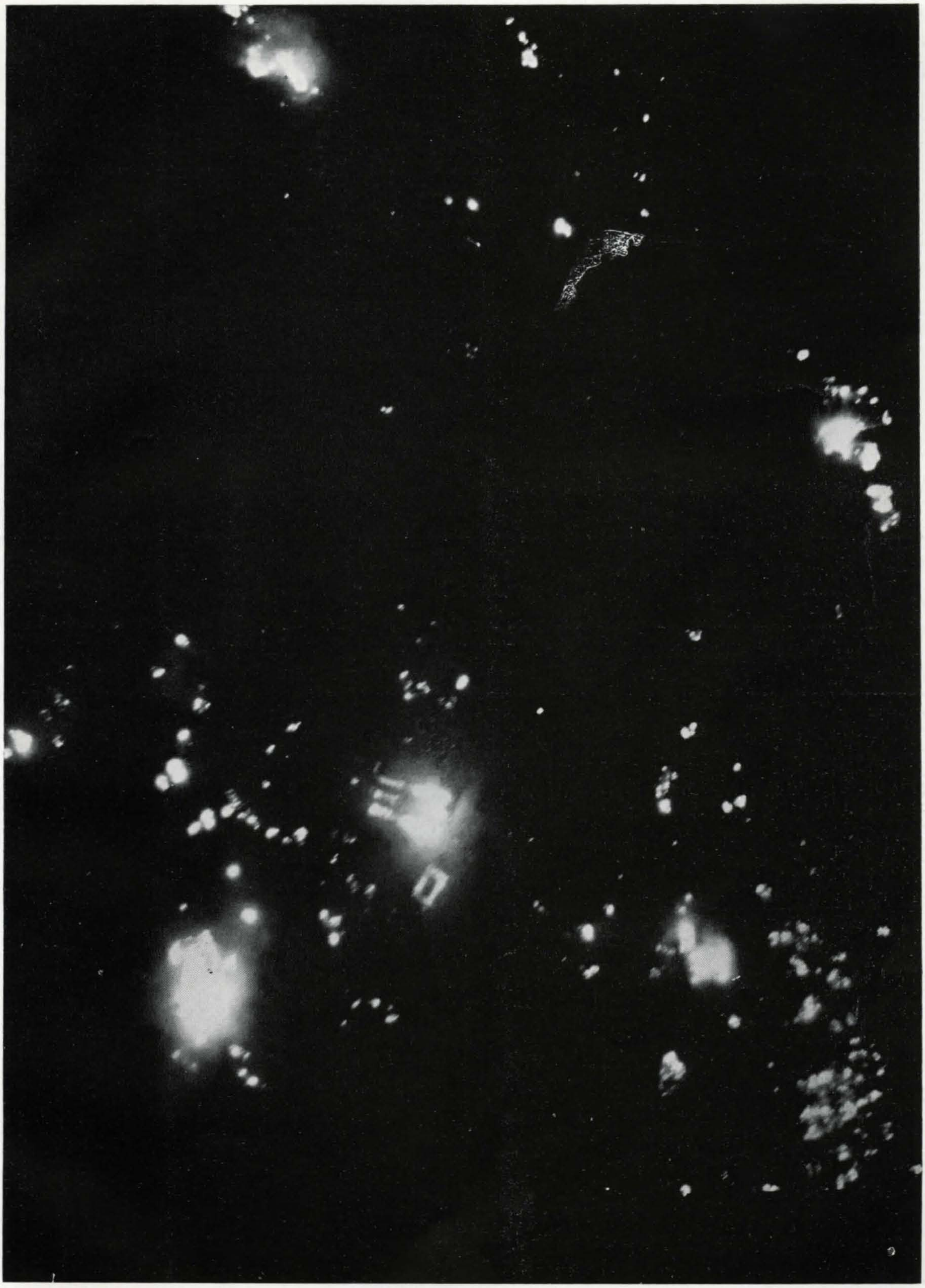


U S STRATEGIC BOMBING SURVEY

CITY PLAN
UBE, HONSHU, JAPAN
FIGURE 1



Night Photo 1 of fires started early in the attack. It shows ground identified buildings, street patterns, direction of wind, location of the shore and river, and extent of fires early in the attack.



Night Photo 2 of fires burning one hour after the attack. It shows the spread of fire that has taken place since Photo 1, the location of new bomb falls, and location of fires that have burned out.

Part 8

EFFECTS OF INCENDIARY BOMB ATTACKS ON NAGOYA, JAPAN

TABLE OF CONTENTS

Page

I. OBJECT OF STUDY 226

II. SUMMARY 226

III. GENERAL INFORMATION 226

IV. THE TARGET 226

V. THE ATTACKS 231

VI. FIRE DEFENSE DATA 232

VII. FIRE DAMAGE AND CASUALTIES 234

VIII. COMMENTS AND CONCLUSIONS 234

IX. REFERENCES 234

Photos 1–3, inclusive

Figures 1–5, inclusive

I. Object of Study

This report attempts to examine ground conditions influencing the effectiveness of four large incendiary attacks on the city of Nagoya, to suggest methods for tactical improvement, and to evaluate the various measures used in fighting incendiary fires.

II. Summary

1. Strategically important Nagoya, Japan's third largest city, was located where the great Nobi Plain meets the head of Ise Bay. Roughly oval in shape, the built-up portion of the city covered about 40 square miles.

2. Industrially, economicallyl, militarily, and commercially the city was of high target priority.

3. Although the dwellings were all combustible, only a central core of the city was highly vulnerable to incendiary attack. The fire department, water system, morale, and general preparations for defense against air attack were excellent.

4. In four major attacks, about 9,780 tons of incendiaries were dropped, resulting in about 12 square miles of damage, approximately 4,000 persons killed and 450,000 made homeless.

5. The excellent fire defense coupled with weather and attack factors prevented maximum fire spread in each of the four attacks.

III. General Information

1. This survey was prepared from information obtained by Major C. F. Castle, fire specialist, during his investigation of industrial targets in and near the city of Nagoya. The data were obtained from the Municipal Statistics Section and Weather Bureau, Bureau of General Affairs. The cooperation of city officials was excellent, but time did not permit complete confirmation of the data submitted. In general, however, the information on extent of water supply, weather and fire department is considered reliable.

2. Fire damage maps (Figures 2 through 5) were prepared from a master map obtained from the Japanese. A careful check by photo interpretation proved this damage information to be essentially accurate.

IV. The Target

1. *General.* The city of Nagoya is located at the eastern extremity of the head of Ise Bay and at the southern end of Nobi Plain, one of the most productive agricultural regions in Japan. The plain extends southwestward toward the cities of Kuwana and Yokkaichi and is fringed by mountains that parallel the coast. Included in this extensive delta flat are the large estuaries of the Shonai, which wraps itself around the west and north limits of Nagoya, and the Ibi and Kiso Rivers. The city's normal population of 1,160,000 in December 1944 was reduced to 592,765 by May 1945 (National Registration Census), because of migrations to suburban areas, national conscription, and casualties from air attacks. The city was modern by Japanese standards, having mushroomed out in the previous ten years, and included scattered steel and reinforced-concrete buildings; this same growth, however, resulted in flimsy residential areas typical of older Japanese cities. The built-up section of the city covered about 40 square miles, of which about 30 were residential.

2. *Industrial.* Nagoya was one of the most important industrial centers in Japan. Ideally located, it was a focal point for both land and water transportation and was served by four trunk railroads. The industrial system was highly modernized and included facilities for producing aircraft, machine tools, ordnance, special steel alloys, electrical equipment, instruments, and chemicals. Most of the prime targets were located in the city proper. Of particular importance was the concentration of aircraft and aircraft engine plants, the largest in any Japanese city; the main factories of Mitsubishi, Aichi, and other large concerns were located here. Next in importance were the large Okuma Iron Works and Mitsubishi Electric Manufacturing Co., the greatest machine tool producers in Japan; Nagoya Arsenal and its subsidiaries; and a multitude of small factories dispersed throughout the city. Major power plants—links in the Central Honshu Power Complex—were located along the harbor. It is estimated that about 6.5 square miles of the city were industrial areas and about 2 square miles were areas of mixed residential and small-scale manufacturing activity.

3. *Military.* The area was one of the most heavily defended in Japan, the bulk of its protection being provided by a concentration of heavy antiaircraft weapons on most approaches that earned it the title of "Flak Alley". Nearly all of the actual military objectives (air fields, barrack areas, and the like) were located outside the city limits, but the city had great military value as a general arsenal and distribution center.

4. *Structures.* The northern section of the city presented a curious mixture of predominantly wood-frame structures, interspersed with buildings of fire-resistive nature (Photos 1 and 2). The southern section included less congested residential areas broken up by parks, canals, river mouths, large industrial areas, and undeveloped land. Residential areas were generally composed of typical one- and two-story dwellings without basements. Commercial structures fell into two categories: those located in the core of the city to the south of Nagoya Castle, predominantly of three or four stories, a few up to nine stories, and usually of modern fire-resistive construction; and those scattered throughout the rest of the city, mostly of two stories and wood frame. Industrial structures varied from flimsy, combustible home shops to modern, fire-resistive plant developments in the south.

5. *Utilities.* The city had a modern water system, two major and three minor power plants, and extensive telephone and sewerage systems. Power was fed in from substations located on the periphery of the densely built-up central area.

6. *Built-upness.* Areas of built-upness were measured as follows:

	(Areas in square miles)		
	Ground area	Roof area	Percent built-up
Residential [1]	4.98	1.96	39.4
Residential [2]	12.78	3.97	31.1
Residential [3]	12.65	2.20	17.4
Manufacturing	6.49	2.64	40.7
Mixed R. and Mfg.	1.97	0.60	30.4
Transportation	0.22	0.02	9.0
Storage	0.64	0.27	42.2
Totals	39.73	11.66	29.3

Residential [1]—Densely built-up (40 percent or more).
Residential [2]—Moderately built-up (20 to 40 percent).
Residential [3]—Sparsely built-up (5 to 20 percent).

7. *Vulnerability of the city*

a. The most highly built-up portion of Nagoya, designated as Zone 1 (Figure 1), was a triangular shaped central core bounded on the east and southeast by the Chuo Railroad line. The Tokaido main line formed the western and southwestern portion of the area. Large prominent Nagoya Castle was at the northern edge and between it and the Tokaido railroad line was a densely built-up northern extension to the area. The zone was roughly three miles long on each side.

b. Zone 2, composed principally of medium built-upness, extended about two miles out from the perimeter of Zone 1 except in the region ½ mile to each side of the Naka Canal.

c. It was estimated that population density in Zone 1 was as high as 70,000 per square mile. Dwelling areas were very congested with sections of 150 to 200 acres bounded by streets 30 to 50 feet wide. Passageways were narrow and alleys were seldom more than 12 feet in width. The physical characteristics of the area prevented quick access to small, isolated fires.

d. The fire breaks in and on the borders of residential areas, more than 90 percent of which fell in Zone 1, were measured as follows:

		Linear miles			
Type	Width	In area	Along border	Total	Per square mile
House removal	150 feet or more	1.0	3.9	4.9	0.98
Natural (streets, canals, etc.	150 feet or more	6.9	6.3	13.2	2.65
Natural (streets, canals, etc.	65 feet to 150 feet	6.1	12.8	18.9	3.80
Industrial areas		2.3	1.2	3.5	0.70
Total		16.3	24.2	40.5	8.13

e. The city developed out from its central core with a minimum of municipal planning and its extremely rapid growth resulted in fairly large concentrations of workers' homes (highly combustible) in Zone 2. The street pattern became quite erratic but followed a roughly rectangular alignment, broken up by a number of canals (Photos 2 and 3) and rivers that flowed through the city and by several newly developed, modern thoroughfares. These factors, together with the heterogeneous nature of the entire southern area, rendered Zone

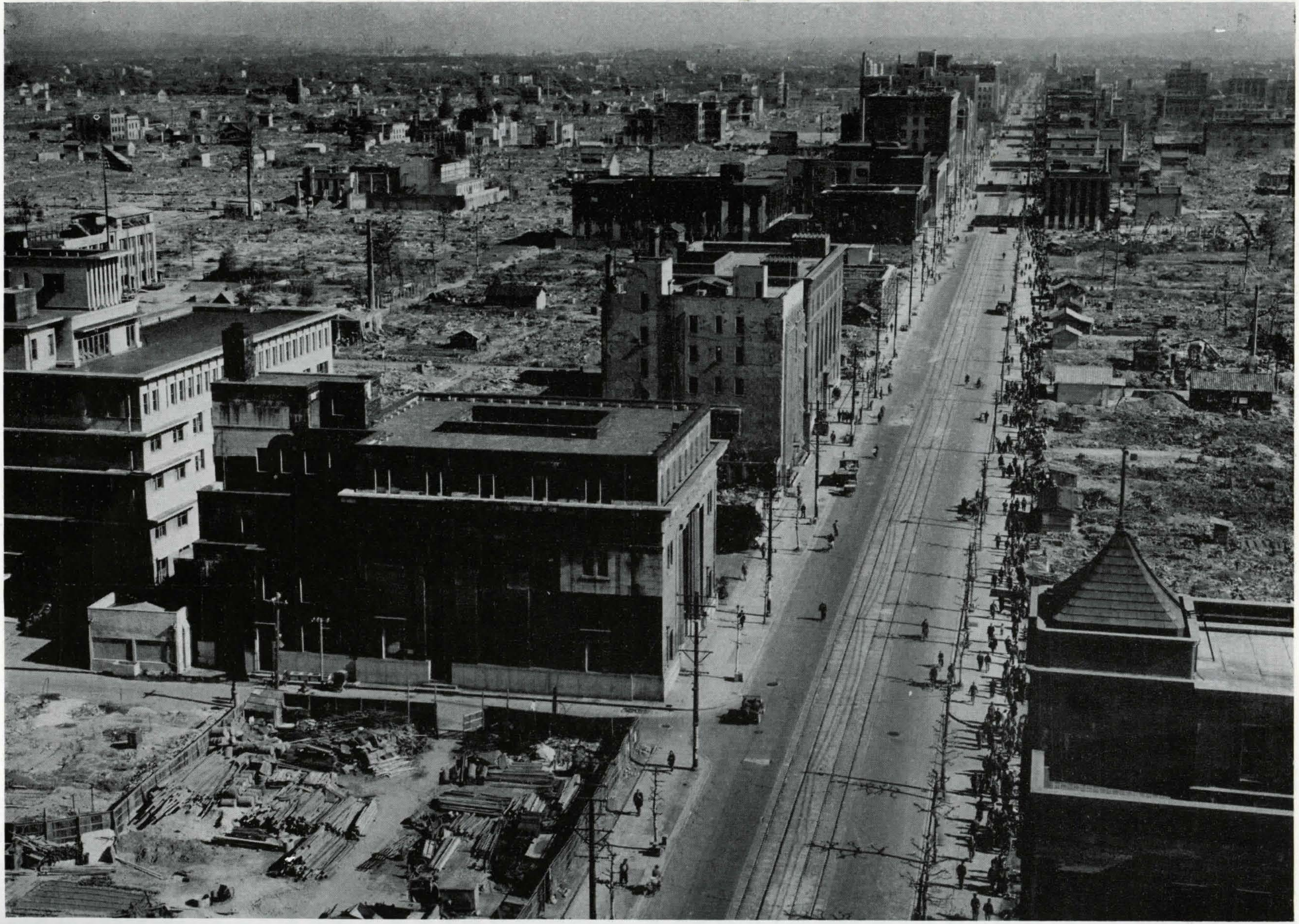


Photo 1.—Nagoya, looking west through Zone 1. Note the interspersion of fire-resistive buildings.

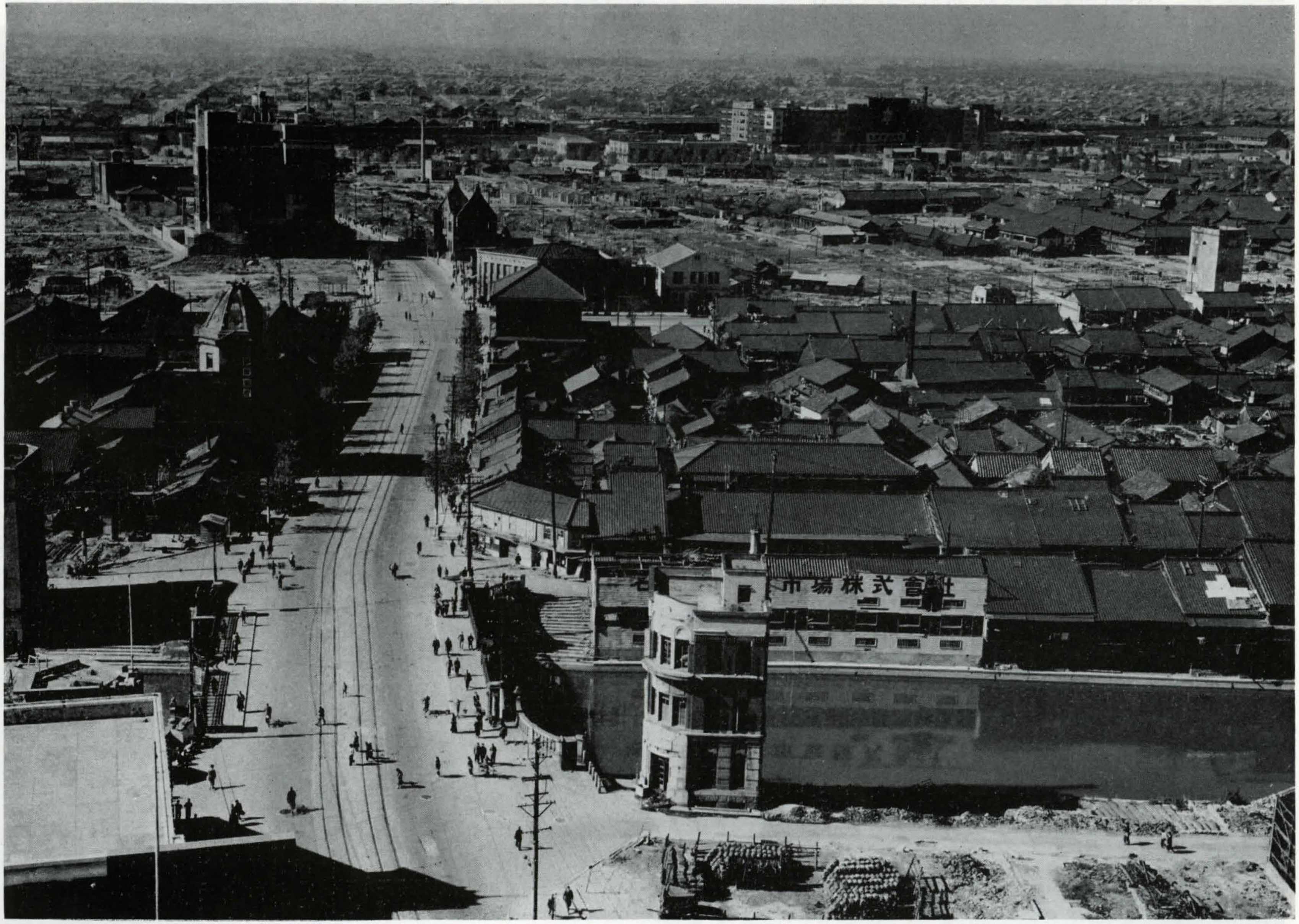


Photo 2. — Nagoya, looking west through Zone 1. Note possible fire-breaking action of canal (foreground) and N-S street (one square distant).

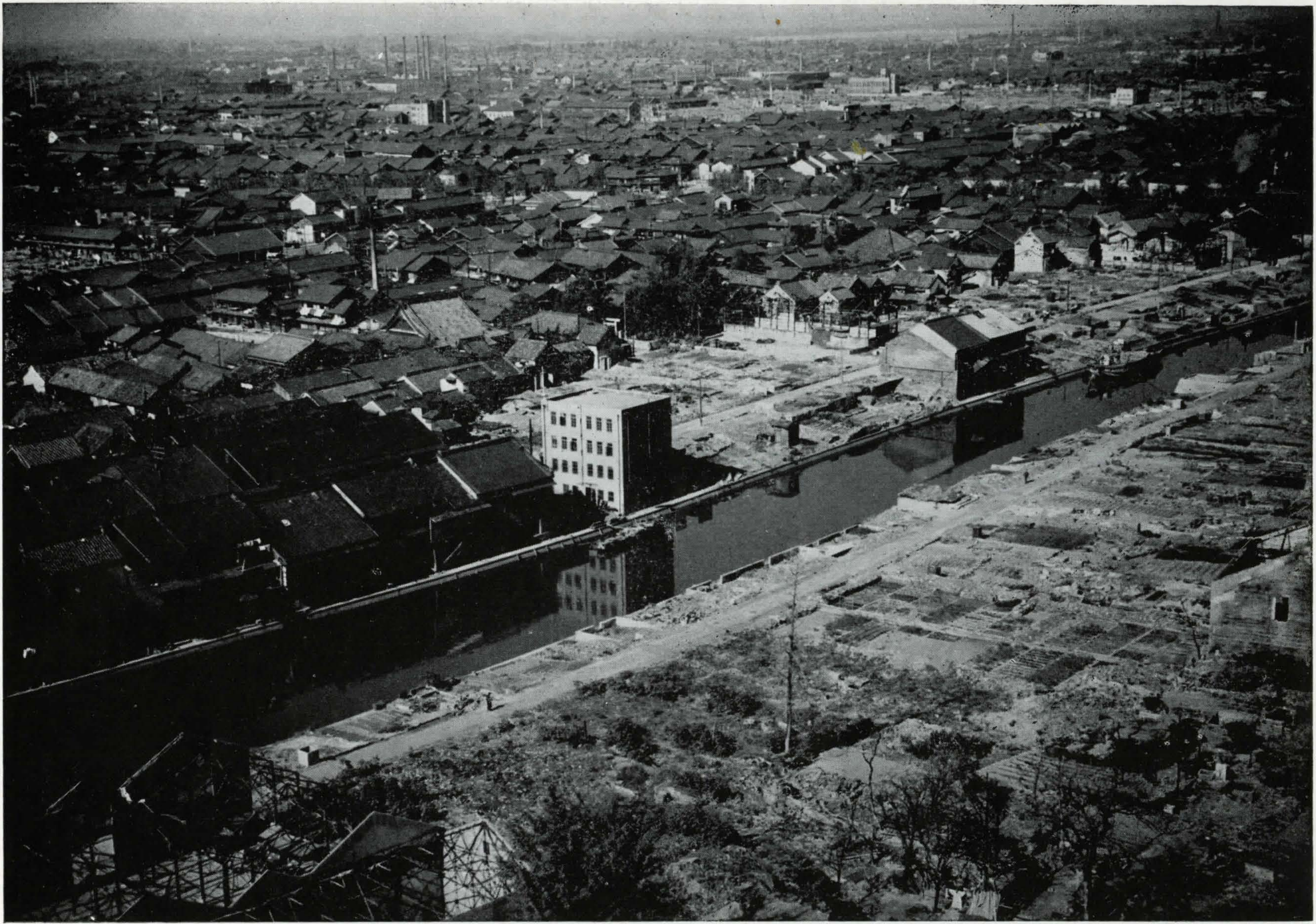


Photo 3. — Nagoya, area arjacent to that in Photo 2, looking northwest. The canal was either jumped by fire or straddled by bombs.

2 considerably less vulnerable to fire than Zone 1.

V. The Attacks

1. *Specific.* Of the nine Nagoya attacks listed by the Twentieth AF, five had negligible effect on urban areas because either they used high-explosive bombs on specific industrial targets, or else the size of the force attacking the urban area was small and the bombing inaccurate. The four remaining major attacks are tabulated below:

	41	44	174	176	Totals
Date	11/3	18/3	13/5	16/5	-------
Planes over target	280	290	472	457	1,499
Number aiming points	3	3	4	4	-------
Altitude (1,000 feet)	6.8–7.3	4.0–7.5	12.0–20.5	6.6–18.3	-------
Intervalometer (feet):	100	100	25	50	-------
Pathfinders					
Main force	100	50	25	50	-------
Total tons dropped	1,793	1,863	2,515	3,609	9,780
Total tons HE	0	19	0	0	19
Total tons M69	1,689	274	2,515	75	4,553
Total tons M47	104	959	0	127	1,190
Total tons M50	0	116	0	3,407	3,523
Total tons M76	0	495	0	0	495
Clusters open (1,000 feet)	2.0–2.5	2.0–3.0	5.0	3.0	-------
Time over target (minutes)	178	164	80	173	-------

2. *General.* The four missions were about equally subjected to flak and fighter opposition and experienced few operational failures.

a. Mission 41 was a night attack planned from information obtained from the preceding (Mission 40) Tokyo attack. Intervalometers, however, were set for a greater spread to result, so it was thought, in more damage. The planes came over Nagoya from the south on an up-wind run; aiming points were staggered and far enough apart to lessen the possibilities of their being obscured by smoke. This precaution was only partly effective: the Tactical Mission Report (Reference 1) states that about one-third of the force "... found the aiming points smoke covered and used radar bombing methods ..." and that "one Wing hit its aiming point, ... the other two Wings were short." A comparison of aiming points with extent of fire damage, moreover, confirmed the fact that a large part of the force bombed short of the target area. This probably resulted in many bombs falling either too far to leeward to obtain maximum fire spread, or else into areas of less built-upness.

b. Mission 44 was a night attack planned from information obtained from the preceding (Mission 43) Kobe attack. Emphasis was placed on compressibility of force, i.e., sending as many planes over the target in as short a time as possible. Fifty-foot intervalometer settings were used. Every third aircraft carried two 500-pound GP bombs as antipersonnel weapons. As in Mission 41, the attack was up wind from the south and aiming points were chosen so that smoke from the bombing of one Wing would not obscure the aiming points of the others. Again, the Mission Report (Reference 2) states that "... as a result of smoke, the majority of the bombing was accomplished exclusively by radar." An examination of aiming points and plotted damage indicated that one of the three Wings bombed short of its aiming point west of Nagoya Castle, so that its bombs fell in a Residential$_2$ area instead of a Residential$_1$ area. Difficulty over the target resulted from blinding searchlights, dummy fires, and radar interference.

c. Mission 174 was a special day attack. Smoke was again the main problem. A down-wind run from the west was planned and "the aiming points were so arranged that those to the east were to be bombed first and those to the west ... last ..." so that "... those bombing last would not have their visibility restricted by smoke from fires started by earlier formations" (Reference 3). Surface winds, however, were not exactly as predicted and more of a cross wind from the north was encountered so that, once again, "... the greatest difficulty ... arose from the smoke over the target area for the later formations. Its presence necessitated the use of offset reference points in several cases, but this type of bombing was handicapped by the limited field of vision of the bombsight and the wide area covered by the smoke." (Reference 3). Most of the bombs fell in areas of medium built-upness (as indicated on Figure 4).

d. Mission 176 was a night attack similar to missions 41 and 44 except that the M50 bomb was chosen as a more effective weapon against the dock areas and industrial targets in the south of the city. A down-wind run from the west was chosen and special attention given to reducing the time of attack to one hour and to avoiding smoke and thermal currents. The attack actually lasted close to three hours, and smoke and thermal current difficulties were not overcome, about half of the planes being forced to bomb from 15,000 feet (Reference 4).

VI. Fire Defense Data

1. *Individuals*

a. The people were generally well trained and disciplined. Fire-fighting instructions were broadcast by radio.

b. Almost without exception, each of the 270,000 families in Nagoya had some sort of air-raid shelter; in addition, there were two or three public shelters located in each of the city's 2,600 Cho. (A Cho included 100 to 150 dwellings). Most of these, however, were flimsy and primitive. There were many deaths by fire and suffocation within shelters, but exact data on these casualties were not available to the surveying team.

2. *Alarm system*

a. As soon as it was felt that the city might be attacked, Tokai Army Headquarters telephoned a warning to three agencies: one, the Nagoya Broadcasting Station and Communication Bureau, broadcast the warning over its regular network; another, the city hall, sounded the "alert" with its powerful electric siren; the third, the Aichi Prefectural Office, telephoned each fire and police station which, in turn, telephoned the civilian-defense stations, factories, department stores and other large institutions in its Cho. About half the defense corps and part-time firemen were mobilized at their posts at the time of "alert".

b. The "alarm" proper was disseminated through the same channels: the people were notified by radio; the city hall siren screamd the "alarm" signal; civilian-defense stations rang alarm bells.

c. Fires were reported by telephone from watch towers to the prefectural office.

3. *Fire fighters and their equipment.* A summary follows:

Personnel

1,933	full-time firemen
22,186	members of defense corps and part-time firemen
24,119	Total

Equipment	Total	Damaged	On hand by end of war
Large fire engines (probably 500 gpm)	265	36	229
Small fire engines (probably 250 gpm)	183	82	101
Gasoline pumpers (probably 250 gpm)	555	239	316
Large hand pumpers (capacity unknown)	743	293	450
Small hand pumpers (capacity unknown)	3,888	3,385	503
Hydrants	7,500	--------	--------

4. *Water supply*

a. The municipal water system was one of the best in Japan. The intake was high up on the Kiso River in the city of Inuyama. The water was fed by gravity through 36-inch mains to Nabeya, where 28 ponds were capable of filtering 80 million gallons daily, then through city mains to the northern section of the city and the large Higashiyama reservoir and elevated tank which had a capacity of 20,500,000 gallons. Fifteen electric pumps, totalling 2,900 horsepower could supply 83 million gallons per day to the city's mains at a pressure of 7 to 35 pounds per square inch. A 900 horsepower Diesel-driven pump was kept in reserve in case of power failure. The percentages of various sized mains, 16 inches or more in diameter, were as follows:

16 inch	41 percent
20 inch	15 percent
24 inch	18 percent
28 inch	9 percent
32 inch	2 percent
36 inch	4 percent
42 inch	11 percent

b. In addition, well water was utilized to supply the section of the city west of the Tokaido railroad line and between it and Nagoya Castle; a smaller well system existed north of Tsurumi Park.

c. The city's water consumption before the war averaged 71 million gallons per day; after the war, 26 million gallons per day.

4. *Fighting the fires*

a. City officials put special emphasis on the protection of the central built-up core of the city. The greatest concentration of fire department personnel and equipment was stationed for expedient access to any of its sections.

b. The plan of defense by the fire department stressed confining fires to previously prepared areas and attacking them along their perimeters.

c. The direction and velocity of the wind were taken into consideration. The winds during the four attacks under discussion were not conducive to spreading conflagration. Their velocities and directions during attacks are summarized below (note location of weather station on Figure 1).

Mission	41	44	174	176
Average velocity (mph)	7.6	6.9	5.1	5.3
Maximum velocity	14.7	8.1	7.4	10.8
Direction	N	N	NNW	NNE

It was decided by the fire department to dispatch light equipment and hand pumpers to the windward edges of fires and to concentrate heavier equipment and the bulk of available man power to leeward.

d. In practice, the fire-fighting plan proved successful. The fires were fought until they were finally controlled or until they were driven against natural or man-made obstacles. Streets were usually clear of debris, so that equipment had direct access to fires. Fire fighters succeeded in not getting trapped in the center of a fire. Control was obtained in windward sections by orthodox dousing with water. The leeward portions generally burned themselves out against parks, railroad beds, man-made firebreaks, wide roads, canals, resistive structures and, especially in the second attack, previously burned out sections. Firebreaks (Section IV, 6, *d*) retained about 53 percent of the fires to which they were subjected; a detailed tabulation follows:

Efficiency of firebreaks in residential areas

(Distances in linear miles)

Width	length	Subjected to fire	Percent total	Fire stopped [1]	Percent stopped
150 feet or over	18.1	9.2	50.8	6.9	75.0
65 feet to 150 feet	18.9	11.2	59.2	3.9	34.8
Total	37.0	20.4	55.1	10.8	52.9

[1] Fires were considered "stopped" where incendiary damage existed directly on one side of the firebreak only. This is, therefore, an assessment of minimum efficiency because fires on both sides were often caused by bombs falling on both sides and not by fire spread.

It is interesting to note that the wider firebreaks were more than twice as effective as the narrower ones.

e. The water system remained in good working order and the emergency pump never had to be used. The remote location of distribution and pumping stations near the outskirts of the city kept them from being hit. Arterial mains suffered more than 60 breaks as a result of high explosives, and smaller distribution mains were severed in more than 800 places, so that sections of the city were sometimes without sufficient water pressure.

f. The fires resulting from the first attack were difficult to control principally in Residential$_1$ areas where fires merged together forming larger conflagrations. Scattered incidents were numerous (394 separate fire areas were positively identified) and, although the fire department had to deploy its equipment, all of the small blazes in Residential$_2$ areas were quickly brought under control (Figure 2).

g. The second attack, which emphasized "compression", was the most concentrated of the four. Only 129 separate fire areas were positively identified. Large fires were started in Residential$_1$ areas but these were brought under control partly because bombs were dropped too short a distance to the windward of previous damage for maximum fire spread, and the burned-out area from the attack of the week before acted as an efficient firebreak (Figure 3).

h. The third attack concentrated on the Residential$_2$ areas north of Nagoya Castle (Figure 4). One hundred and thirty-one separate blazes were identified. The only large conflagration was started in the northern extension to Zone 1, west of Nagoya Castle; this burned itself out against a 200-foot, man-made firebreak in the south. The wind averaged 5.1 miles per hour, the lowest for any of the attacks. The fire department's equipment was in good condition as it had not engaged in large-scale operations for two months and repairs had been made.

i. The last attack concentrated on the sparsely built-up southern section and the bulk of the damage occurred in industrial targets and in the clusters of workers' houses (Figure 5). One hundred and thirty-eight separate incidents were identified. The segregation of fires was accomplished fairly easily, although larger areas were isolated for this purpose.

j. The Japanese reported that a period of water pipe inspection and repair, during which all water was shut off and mains were under repair in many places, followed each attack. It seems plausible, in the case of Nagoya, that attacks following each other by one or two days would have accomplished more damage, even if the bomb loads of each were substantially lighter than those usually employed.

k. The Japanese also indicated that attacks following each other closely tended to catch personnel exhausted and equipment in poor condition.

VII. Fire Damage and Casualties

a. One hundred and thirteen thousand four hundred and sixty buildings of all types were completely destroyed, and 4,646 were damaged by fire. Damage to built-up areas follows:

1. *Material Damage*

	Square miles damaged (all types)	Square miles damaged per 1000 tons of bombs dropped on target
Mission 41	2.05	1.14
Mission 44	2.95	1.58
Mission 174	3.15	1.25
Mission 176	3.82	1.06
Total	11.97	(All) 1.25

b. Breakdown of damage by areas of built-upness

Built-upness	Average percent built-up	Square miles damaged
Residential 1	39.4	3.76
Residential 2	31.1	3.75
Residential 3	17.4	1.30
Manufacturing	40.7	2.06
Mixed	30.4	1.96
Transportation	9.0	0.02
Storage	42.2	0.12
Total		11.97

2. *Personnel Losses*

	All attacks	Missions 41, 44, 174, 176
Dead	7,724	3,866
Severely injured	4,378	1,843
Slightly injured	6,155	4,311
Total casualties	18,257	10,020
Homeless	522,951	452,701

VIII. Comments and Conclusions

1. Only the central residential section of Nagoya was highly vulnerable to incendiary attack.

2. The city, with an excellent fire department, relatively good water system, disciplined civilian population, many fire-resistive buildings, a multitude of parks, wide streets, canals, and other firebreaks, was better prepared for incendiary attacks than most other Japanese cities.

3. Low wind velocity appears to have been a principal factor in the lack of fire spread.

4. Obscuring smoke from fires started by earlier formations caused some later formations to bomb short of their aiming points. Sometimes, consequently (as in the case of Mission 41), many bombs fell too far to leeward to produce maximum fire spread; sometimes (as in the case of Mission 174) bombs fell in a less densely built-up area.

5. The selection of aiming points in relation to previously burned-out areas and the direction of the wind was found to be important. Attacks directed to windward sections should be as far away from previous damage as the choice of combustible areas allows; attacks directed to leeward sections should be as close to previous damage as bombing accuracy renders feasible.

6. Better results would probably have been obtained, if key installations of the water system had been damaged prior to or during the incendiary attacks.

7. It is probable that attacks closely following each other could do more damage than those effected at sporadic intervals, because the people would be given no time to recuperate and fire defenses would be in poor condition.

8. Fighting a fire along its perimeter is more effective in keeping it under control than spending the same effort on fires within the perimeter.

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6 Junkers Aircraft and Aero Engine Works, Dessau, Germany
7 Erla Maschinenwerke G m b H, Heiterblick, German
8 A T G Maschinenbau, G m b H, Leipzig (Mockau), Germany
9 Gothaer Waggonfabrik, A G, Gotha, Germany
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14 Wiener Neustaedter Flugzeugwerke, Wiener Neustadt, Austria

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16 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
17 Bavarian Motor Works, Inc, Eisenach & Durrerhof, Germany
18 Bayerische Motorenwerke A G (BMW) Munich, Germany
19 Henschel Flugmotorenwerke, Kassel, Germany

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37 A Detailed Study of the Effects of Area Bombing on Darmstadt
38 A Detailed Study of the Effects of Area Bombing on Lubeck
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140 Submarine Pens, Brest, France
141 Powder Plant, Angoulene, France
142 Powder Plant, Bergerac, France
143 Coking Plants, Montigny & Liege, Belgium
144 Fort St. Blaise Verdun Group, Metz, France
145 Gnome et Rhone, Limoges, France
146 Michelin Tire Factory, Clermont-Ferrand, France
147 Gnome et Rhone Aero Engine Factory, Le Mans, France
148 Kugelfischer Bearing Ball Plant, Ebelsbach, Germany
149 Louis Breguet Aircraft Plant, Toulouse, France
150 S. N. C. A. S. E. Aircraft Plant, Toulouse, France
151 A. I. A. Aircraft Plant, Toulouse, France
152 V Weapons in London
153 City Area of Krefeld
154 Public Air Raid Shelters in Germany
155 Goldenberg Thermal Electric Power Station, Knapsack, Germany
156 Brauweiler Transformer & Switching Station, Brauweiler, Germany
157 Storage Depot, Nahbollenbach, Germany
158 Railway and Road Bridge, Bad Munster, Germany
159 Railway Bridge, Eller, Germany
160 Gustloff-Werke Weimar, Weimar, Germany
161 Henschell & Sohn G m b H, Kassel, Germany
162 Area Survey at Pirmasens, Germany
163 Hanomag, Hanover, Germany
164 M A N Werke Augsburg, Augsburg, Germany
165 Friedrich Krupp A G, Essen, Germany
166 Erla Maschinenwerke, G m b H, Heiterblick, Germany
167 A T G Maschinenbau G m b H, Mockau, Germany
168 Erla Maschinenwerke G m b H, Mockau, Germany
169 Bayerische Motorenwerke, Durrerhof, Germany
170 Mittel-Deutsche Motorenwerke G m b H, Taucha, Germany
171 Submarine Pens Deutsche-Werft, Hamburg, Germany
172 Multi-Storied Structures, Hamburg, Germany
173 Continental Gummiwerke, Hanover, Germany
174 Kassel Marshalling Yards, Kassel, Germany
175 Ammoniawerke, Merseburg-Leuna, Germany
176 Brown Boveri et Cie, Mannheim, Kafertal, Germany
177 Adam Opel A G, Russelsheim, Germany
178 Daimler-Benz A G, Unterturkheim, Germany
179 Valentin Submarine Assembly, Farge, Germany
180 Volkswaggonwerke, Fallersleben, Germany
181 Railway Viaduct at Bielefeld, Germany
182 Ship Yards Howaldtswerke, Hamburg, Germany
183 Blohm and Voss Shipyards, Hamburg, Germany
184 Daimler-Benz A G, Mannheim, Germany
185 Synthetic Oil Plant, Meerbeck-Hamburg, Germany
186 Gewerkschaft Victor, Castrop-Rauxel, Germany
187 Klockner Humboldt Deutz, Ulm, Germany
188 Ruhroel Hydrogenation Plant, Bottrop-Boy, Germany
189 Neukirchen Eisenwerke A G, Neukirchen, Germany
190 Railway Viaduct at Altenbecken, Germany
191 Railway Viaduct at Arnsburg, Germany
192 Deurag-Nerag Refineries, Misburg, Germany

193 Fire Raids on German Cities
194 I G Farbenindustrie, Ludwigshafen, Germany, Vol I and Vol II
195 Roundhouse in Marshalling Yard, Ulm, Germany
196 I G Farbenindustrie, Leverkusen, Germany
197 Chemische-Werke, Huels, Germany
198 Gremberg Marshalling Yard, Gremberg, Germany
199 Locomotive Shops and Bridges at Hamm, Germany

TRANSPORTATION DIVISION

*200 The Effects of Strategic Bombing on German Transportation
201 Rail Operations Over the Brenner Pass
202 Effects of Bombing on Railroad Installations in Regensburg, Nurnberg and Munich Divisions
203 German Locomotive Industry During the War
204 German Military Railroad Traffic

UTILITIES DIVISION

*205 German Electric Utilities Industry Report
206 1 to 10 in Vol I "Utilities Division Plant Reports"
207 11 to 20 in Vol II "Utilities Division Plant Reports"
208 21 Rheinische-Westfalische Elektrizitaetswerk A G

Pacific War

OFFICE OF THE CHAIRMAN

*1 Summary Report (Pacific War)
*2 Japan's Struggle to End The War
*3 The Effects of Atomic Bombs on Hiroshima and Nagasaki

CIVILIAN STUDIES

Civilian Defense Division

4 Field Report Covering Air Raid Protection and Allied Subjects, Tokyo, Japan
5 Field Report Covering Air Raid Protection and Allied Subjects, Nagasaki, Japan.
*6 Field Report Covering Air Raid Protection and Allied Subjects, Kyoto, Japan
7 Field Report Covering Air Raid Protection and Allied Subjects, Kobe, Japan
8 Field Report Covering Air Raid Protection and Allied Subjects, Osaka, Japan
9 Field Report Covering Air Raid Protection and Allied Subjects, Hiroshima, Japan—No. 1
*10 Summary Report Covering Air Raid Protection and Allied Subjects in Japan
*11 Final Report Covering Air Raid Protection and Allied Subjects in Japan

Medical Division

*12 The Effects of Bombing on Health and Medical Services in Japan
*13 The Effects of Atomic Bombs on Health and Medical Services in Hiroshima and Nagasaki

Morale Division

*14 The Effects of Strategic Bombing on Japanese Morale

ECONOMIC STUDIES

Aircraft Division

*15 The Japanese Aircraft Industry
*16 Mitsubishi Heavy Industries, Ltd.
Corporation Report No. I
(Mitsubishi Jukogyo KK)
(Airframes & Engines)
*17 Nakajima Aircraft Company, Ltd.
Corporation Report No. II
(Nakajima Hikoki KK)
(Airframes & Engines)
*18 Kawanishi Aircraft Company
Corporation Report No. III
(Kawanishi Kokuki Kabushiki Kaisha)
(Airframes)
*19 Kawasaki Aircraft Industries Company, Inc.
Corporation Report No. IV
(Kawasaki Kokuki Kogyo Kabushiki Kaisha)
(Airframes & Engines)
*20 Aichi Aircraft Company
Corporation Report No. V
(Aichi Kokuki KK)
(Airframes & Engines)
*21 Sumitomo Metal Industries, Propeller Division
Corporation Report No. VI
(Sumitomo Kinzoku Kogyo KK, Puropera Seizosho)
(Propellers)
*22 Hitachi Aircraft Company
Corporation Report No. VII
(Hitachi Kokuki KK)
(Airframes & Engines)
*23 Japan International Air Industries, Ltd.
Corporation Report No. VIII
(Nippon Kokusai Koku Kogyo KK)
(Airframes)
*24 Japan Musical Instrument Manufacturing Company
Corporation Report No. IX
(Nippon Gakki Seizo KK)
(Propellers)
*25 Tachikawa Aircraft Company
Corporation Report No. X
(Tachikawa Hikoki KK)
(Airframes)
*26 Fuji Airplane Company
Corporation Report No. XI
(Fuji Hikoki KK)
(Airframes)
*27 Showa Airplane Company
Corporation Report No. XII
(Showa Hikoki Kogyo KK)
(Airframes)
*28 Ishikawajima Aircraft Industries Company, Ltd.
Corporation Report No. XIII
(Ishikawajima Koku Kogyo Kabushiki Kaisha)
(Engines)
*29 Nippon Airplane Company
Corporation Report No. XIV
(Nippon Hikoki KK)
(Airframes)

*30 Kyushu Airplane Company
  Corporation Report No. XV
  (Kyushu Hikoki KK)
  (Airframes)
*31 Shoda Engineering Company
  Corporation Report No. XVI
  (Shoda Seisakujo)
  (Components)
*32 Mitaka Aircraft Industries
  Corporation Report No. XVII
  (Mitaka Koku Kogyo Kabushiki Kaisha)
  (Components)
*33 Nissan Automobile Company
  Corporation Report No. XVIII
  (Nissan Jidosha KK)
  (Engines)
*34 Army Air Arsenal & Navy Air Depots
  Corporation Report No. XIX
  (Airframes & Engines)
*35 Underground Production of Japanese Aircraft
  Report No. XX

Basic Materials Division

*36 Coal and Metals in Japan's War Economy

Capital Goods, Equipment and Construction Division

*37 The Japanese Construction Industry
*38 Japanese Electrical Equipment
*39 The Japanese Machine Building Industry

Electric Power Division

*40 The Electric Power Industry of Japan
*41 The Electric Power Industry of Japan (Plant Reports)

Manpower, Food and Civilian Supplies Division

*42 The Japanese Wartime Standard of Living and Utilization of Manpower

Military Supplies Division

*43 Japanese War Production Industries
*44 Japanese Naval Ordnance
45 Japanese Army Ordnance
*46 Japanese Naval Shipbuilding
*47 Japanese Motor Vehicle Industry
*48 Japanese Merchant Shipbuilding

Oil and Chemical Division

49 Chemicals in Japan's War
50 Chemicals in Japan's War—Appendix
51 Oil in Japan's War
52 Oil in Japan's War—Appendix

Over-all Economic Effects Division

*53 The Effects of Strategic Bombing on Japan's War Economy (Including Appendix A: U. S. Economic Intelligence on Japan—Analysis and Comparison; Appendix B: Gross National Product on Japan and Its Components; Appendix C: Statistical Sources).

Transportation Division

*54 The War Against Japanese Transportation, 1941–1945

Urban Areas Division

*55 Effects of Air Attack on Japanese Urban Economy (Summary Report)
*56 Effects of Air Attack on Urban Complex Tokyo-Kawasaki-Yokohama
*57 Effects of Air Attack on the City of Nagoya
*58 Effects of Air Attack on Osaka-Kobe-Kyoto
59 Effects of Air Attack on the City of Nagasaki
60 Effects of Air Attack on the City of Hiroshima

MILITARY STUDIES

Military Analysis Division

61 Air Forces Allied with the United States in the War Against Japan
62 Japanese Air Power
63 Japanese Air Weapons and Tactics
64 The Effect of Air Action on Japanese Ground Army Logistics
65 Employment of Forces Under the Southwest Pacific Command
66 The Strategic Air Operations of Very Heavy Bombardment in the War Against Japan (Twentieth Air Force)
67 Air Operations in China, Burma, India—World War II
68 The Air Transport Command in the War Against Japan
69 The Thirteenth Air Force in the War Against Japan
70 The Seventh and Eleventh Air Forces in the War Against Japan
71 The Fifth Air Force in the War Against Japan

Naval Analysis Division

*72 The Interrogations of Japanese Officials (Vols. I and II)
*73 Campaigns of the Pacific War
*74 The Reduction of Wake Island
*75 The Allied Campaign Against Rabaul.
76 The American Campaign Against Wotje, Maloelap, Mille, and Jaluit (Vols. I, II and III)
*77 The Reduction of Truk
78 The Offensive Mine Laying Campaign Against Japan
79 Report of Ships Bombardment Survey Party—Foreword, Introduction, Conclusions, and General Summary
80 Report of Ships Bombardment Survey Party (Enclosure A), Kamaishi Area
81 Report of Ships Bombardment Survey Party (Enclosure B), Hamamatsu Area
82 Report of Ships Bombardment Survey Party (Enclosure C), Hitachi Area
83 Report of Ships Bombardment Survey Party (Enclosure D), Hakodate Area
84 Report of Ships Bombardment Survey Party (Enclosure E), Muroran Area
85 Report of Ships Bombardment Survey Party (Enclosure F), Shimizu Area
86 Report of Ships Bombardment Survey Party (Enclosures G and H), Shionomi-Saki and Nojima-Saki Areas

87 Report of Ships Bombardment Survey Party (Enclosure I), Comments and Data on Effectiveness of Ammunition

88 Report of Ships Bombardment Survey Party (Enclosure J), Comments and Data on Accuracy of Firing

89 Reports of Ships Bombardment Survey Party (Enclosure K), Effects of Surface Bombardments on Japanese War Potential

Physical Damage Division

90 Effect of the Incendiary Bomb Attacks on Japan (a Report on Eight Cities)

91 The Effects of the Ten Thousand Pound Bomb on Japanese Targets (a Report on Nine Incidents)

92 Effects of the Atomic Bomb on Hiroshima, Japan

93 Effects of the Atomic Bomb on Nagasaki, Japan

94 Effects of the Four Thousand Pound Bomb on Japanese Targets (a Report on Five Incidents)

95 Effects of Two Thousand, One Thousand, and Five Hundred Pound Bombs on Japanese Targets (a Report on Eight Incidents)

96 A Report on Physical Damage in Japan (Summary Report)

G–2 Division

97 Japanese Military and Naval Intelligence

98 Evaluation of Photographic Intelligence in the Japanese Homeland, Part I, *Comprehensive Report*

99 Evaluation of Photographic Intelligence in the Japanese Homeland, Part II, *Airfields*

100 Evaluation of Photographic Intelligence in the Japanese Homeland, Part III, *Computed Bomb Plotting*

101 Evaluation of Photographic Intelligence in the Japanese Homeland, Part IV, *Urban Area Analysis*

102 Evaluation of Photographic Intelligence in the Japanese Homeland, Part V, *Camouflage*

103 Evaluation of Photographic Intelligence in the Japanese Homeland, Part VI, *Shipping*

104 Evaluation of Photographic Intelligence in the Japanese Homeland, Part VII, *Electronics*

105 Evaluation of Photographic Intelligence in the Japanese Homeland, Part VIII, *Beach Intelligence*

*106 Evaluation of Photographic Intelligence in the Japanese Homeland, Part IX, *Artillery*

*107 Evaluation of Photographic Intelligence in the Japanese Homeland, Part X, *Roads and Railroads*

108 Evaluation of Photographic Intelligence in the Japanese Homeland, Part XI, *Industrial Analysis*

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